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Report on the Condition of the Niagara Railway Suspension Bridge, 1860. By JOHN A. ROEBLING, Civ. Eng.

To the Presidents and Directors of the Niagara Falls Suspension, and Niagara Falls International Bridge Companies.

GENTLEMEN :—After an absence of two years, I have again visited the Niagara Railway Suspension Bridge, and have, during a stay of three days, on the 18th, 19th, and 20th of July, made a thorough examination of the work. I now present to you the following report :

The Niagara Bridge was opened for railway traffic on the 18th of March, 1855; the lower floor for common travel was completed and in use the year previous. The number of trains and trips of single engines, which at the present time pass over the Bridge in twenty-four hours, averages about forty-five. This great traffic accounts for the rapid wear of the rails, many of which require renewal.

After a thorough examination of all parts of the work, I am unable to report any change.

The camber of the floors and the deflection of the cables, as you well know, depend upon the temperature of the atmosphere. The relative level of the floors is the same as it was in 1855.

In order to be better enabled to judge whether the stiffness of the superstructure has been impaired by a five years traffic, I placed a

leveling instrument between the towers on the New York side, and observed the process of gradual deflection caused by five trains.

A train, composed of the engine "Essex," and tender, of 35 tons weight, drawing 10 empty cars, produced a deflection in the centre of	0·462 feet.
A small engine, drawing 2 loaded passenger cars, 1 baggage car, and 1 loaded cattle car,	0·510 "
Another light engine, with 5 loaded passenger cars, and 1 baggage car,	0·520 "
The engine "Essex," and tender alone,	0·315 "
The same engine returning with 8 loaded cattle cars, each holding 17 to 18 cattle of the largest size,	0·789 "

A short but heavy train, such as the last, when in the centre of the Bridge between the stays, produces the greatest deflection comparatively. A longer train, loaded at the same rate, and extending over the limits of the stays, deflects the work but little more. In proportion, as the ends of the floor are weighed down, the centre is kept up. By comparing the above observations with those of 1855, we discover no essential difference. The great experimental train, which covered the whole Bridge with loaded cars, propelled by two engines, produced a deflection of ten inches. A similar train passed over now will do the same.

The extreme rise and fall of the floor, owing to the contraction and expansion of the cables, amounts to more than two feet. But the cables being at liberty to contract and expand, this process can never affect their strength.

In my report of 1855 I stated the aggregate ultimate strength of the 4 suspension cables at	12,000 tons.
Permanent weight, supported by cables,	1,000 "
Tension resulting,	1,810 "
Proportion of permanent tension to strength,	1 : 6·63
Tension produced by a train of 250 tons,	452 "
Aggregate tension,	2,262 "
Proportion of working tension to strength,	1 : 5·30

This liberal allowance of strength and freedom from vibration will insure the durability of the cables.

The question has been repeatedly asked, why trains are not allowed to pass over this Bridge at a higher rate of speed than five miles an hour? This limitation is looked upon as a sign of tacitly acknowledged weakness, and has been frequently referred to as a strong argument against suspension bridges for railway purposes.

This matter I discussed in my report of 1855, but I will explain again and more fully. The first great object of this limitation of speed is *safety*. Although it may look somewhat timid in this fast-going age, to see freight trains move at the rate of five miles per hour, and passenger trains at even a less rate, yet when it is considered that this slow speed insures *absolute safety*, no matter what accident may happen to a train—the traveling community ought to be satisfied with this cautious arrangement. What would be gained by a higher speed? Nothing whatever. The Bridge forms a link between two termini, and there is always time to make connections. Passengers will prefer to cross at a slow rate in order to enjoy the splendid scene-

ry during the passage. The track is so constructed as to form a trough of three feet depth between the girders, into which a car or locomotive will instantly drop, the moment it breaks down or leaves the track—provided there is no great headway. Should such an accident happen to a train, the broken-down car, engine, or track, will act as a powerful brake, and will check its motion. When planning the work, absolute safety was made the first condition, and the track has been constructed accordingly. I would also remark in this connexion, that any further addition of fender-pieces to the track, as an additional means of safety, as has been proposed of late, would only prove an unnecessary incumbrance.

A greater speed than five miles per hour for passenger trains should never be permitted for the reasons stated. But should a much heavier freight business have to be accommodated in the future, the speed of freight trains may be increased without injury to the work. All that will be necessary is, to keep the track in perfect order, and to maintain a continuous bearing at the rail joints to prevent concussions. I will further state here, that by an additional expenditure of $20,000, the stiffness of the Bridge may be so far increased as to admit of the highest practicable speed of freight trains, without producing the slightest injurious effect upon the structure. I make this statement deliberately for the information of those professional and unprofessional opponents to suspension railway bridges, who have made it their business to cast doubts upon the permanency of this work. I also expect to demonstrate this when resuming the works on the Kentucky River Bridge, on the Lexington and Danville Railroad, which, when completed, will form a single span of 1224 feet from centre to centre of towers, over a chasm of 300 feet deep.

The wood-work of the Niagara Bridge, being kept well painted, and otherwise well protected, will last forty years and more. The old wooden St. Clair Bridge, at Pittsburgh, Penna., which I removed to make room for a new suspension bridge, recently completed, has stood exactly forty years. All its principal timbers of pine and oak, on removal, were found good and sound. A portion of this material, after being well tarred, has gone into the new suspension floor, and will no doubt render good service for another forty years.

My views of the durability of the cables have undergone no change since 1855; they have only been strengthened by additional experience. This being a subject of great importance and of general interest, I embrace this opportunity to express myself more fully, and thus perhaps to contribute towards a better understanding of the nature of iron.

The fact is well known, that wrought iron under certain conditions will undergo certain radical changes. And so will all kinds of matter. The material universe is not by any means constituted upon the principle of *immutability*. Material existence is but a theatre of change, of breaking down, of reduction, and of reconstruction of the elements of matter. The Egyptian pyramids are even now undergoing a slow process of disintegration. The dry air of that region, slow

in action, is still sure to do its appointed work. And as all human fabrics, being but material constructions, will have to succumb to the same inexorable law, we cannot expect that the Niagara Bridge will form an exception.

Two kinds of changes are known, which will affect the strength of iron and other metals. The one is wrought by the chemical process of oxidation, and can be guarded against effectually, and is so guarded in the Niagara Bridge. All iron and wire within reach, are kept well painted, and thus preserved against rust. The anchor chains and their connexions with the cables, inside of the anchor masonry and in the rock below, after three coats of paint, are protected by the cement grout, which forms a solid envelope, excluding air and moisture.

But aside from the mechanical protection thus afforded, I depend principally, as was explained in my report of 1855, upon the well-known chemical action of calcareous cements in contact with iron. Oxygen has a greater affinity for lime than for iron. So long, therefore, as the cement will combine with oxygen, or, in other words, has not become completely crystallized, which is a very slow process inside of heavy masonry, the iron will be protected. The cement, not exposed to the air, when setting slowly, has a tendency rather to expand than to contract; but suppose there should be cracks around the anchor bars, large enough to admit air and moisture. Water will then find its way through those cracks, but on reaching the iron, will be more or less impregnated with cement, and thus add another protecting coat. The chemical principle, which I have explained here, I apply daily in my factory for the preservation of wire against dampness. I have also carried on direct experiments for a number of years, which have convinced me of the preserving property of calcareous cements in damp situations.

On examining recently the anchor bars of the Monongahela Suspension Bridge at Pittsburgh, built sixteen years ago, I found them perfectly preserved, as far as the cement, in which they are embedded, was removed. To satisfy yourself on this subject, I shall propose in a few years more, to remove the anchor blocks and to examine the upper links of the anchor chains of the Niagara Bridge. It should be remembered, that good cement grout, when not disturbed by any mechanical action or by a current of water, will set perfectly solid, and will become as hard as sand stone in course of time, and without shrinking. The anchor chains of the Niagara Bridge are, in my opinion, effectually guarded against oxidation.

But iron under certain conditions will undergo another change, which is not so well understood, and is indeed as yet a partial mystery. And this fact has been seized upon as an invincible argument against iron bridges generally, and against the Niagara Bridge especially. I refer to the supposed and popularly so-called *granulation* of fibrous wrought iron.

Although this subject has engaged my attention for a series of years, and I have taken pains to obtain correct information, I yet hesitate to express any decided opinions, that would cover the whole

field of investigation. The question at large I consider open yet. This much only I believe to be settled, that good iron will undergo no change in course of time, unless it is acted on by great heat, or is under the influence of strong continuous vibrations under tension.

As an exception to this last proposition, may be cited the case of old anchors and chains, which, after being exposed on the ground or in the ground, a great length of time, had become considerably rusted and reduced in strength. Aside from rusting, magnetic influences were supposed to have been at work in destroying the strength of these irons. But it should be remarked, that none of these cases have been sufficiently well examined to warrant sound conclusions. It is true that the earth forms a great magnet, whose magnetism is maintained by the sun; and that the magnetic condition of all metals is more or less depending upon the great parent magnet. A steel magnet that has lost its power or tension, when buried in the earth, will be restored by its magnetic currents. But how far the cohesion and elasticity of wrought iron may be affected by these currents, we are yet ignorant of. When a bar of iron is drawn apart by a tensile strain, the fractured ends are magnetically excited, and will attract iron filings, at the same time that they become heated. Both phenomena, magnetism as well as heat, will always accompany the forcible rupture of iron, as can be readily ascertained by experiment. The same phenomena are also exhibited when iron is hammered cold, the heat in this case being more apparent than the magnetism.

The cohesion and elasticity of wrought iron, although different properties, appear to be closely related. In speaking of elasticity, I mean the natural elasticity, and not what is produced by the forced process of tempering. And here may be pointed out a marked physical difference between steel and iron. While the hardening or tempering of steel can be carried to almost any degree, that of the latter can not.

Whatever destroys or impairs the elasticity of iron or steel, will also affect its cohesion. And this fact has also a significant magnetic bearing. Tempered or hardened steel possesses more tensile strength than soft steel. Now when tempered steel loses its hardness by annealing, it assimilates nearer to soft iron in its relation to magnetism. Red-hot iron is not attracted by a magnet, while a steel magnet entirely loses its magnetic properties on being heated red hot. Another remarkable fact is, that artificial as well as natural magnets, when *overloaded*, become weakened. And so does the cohesion and elasticity of an iron or steel bar become weakened by overloading.

The limit of elasticity, or of the *recuperating* force, as it might be termed, of iron and steel is generally stated at one-third of their ultimate strength. I am of the opinion that this is much *over*-estimated for soft puddled irons, and *under*-estimated for good hammered charcoal irons, and still more for steel.

The force which holds together the molecules of iron, is termed cohesion. Heat will expand iron, and when applied intensely and continuously, will melt it, and will thus destroy all cohesion, and at

the same time all elasticity and all magnetic tension. It follows, then, that heat of a certain degree is opposed to cohesion and elasticity. And this explains why large masses of wrought iron, when being forged, and thus subjected for a considerable length of time to an annealing process, will, in the centre, become greatly reduced in cohesion and elasticity. The previously existing fibre in the faggots will change into a coarse crystalline texture, because the iron being in a pasty and nearly molten state, and the mechanical effect of hammering being confined to the surface, and not penetrating to the centre, the formation of large crystals will be left undisturbed. Broken car-axles sometimes appear to have undergone a similar change. The fact is, that they generally exhibit a crystalline fracture. But I suspect that many new axles, although manufactured out of fibrous rough-bar, will, when finished and broken *before* they are used, also exhibit a crystalline fracture. In my own practice I have witnessed the fact, that an experienced manufacturer, anxious to satisfy me, did not succeed in manufacturing round bolt of four to five inches diameter out of good fibrous rough-bar, without producing a crystalline texture in the centre. The oftener he piled the iron, the worse the result. On the other hand, I never heard of a failure when the bolt was forged entire under the hammer, out of good and well worked and thoroughly hammered charcoal blooms, their rough ends cut off.

The most fibrous bar iron may be broken so as to present a granular and somewhat crystalline fracture, and this without undergoing any molecular change in the texture. Take a fibrous bar, say ten feet long, but the longer the better, nip it in the centre all around with a cold chisel, then poise the bar upon the short edge of a large anvil, and a short piece of iron, placed eight or nine inches from the edge on the face of the anvil, then strike a few heavy blows upon the nip, so that each blow will cause the bar to rebound, and to vibrate intensely, and the result will be a granular and somewhat crystalline fracture. Now take up the two halves, and nip them again all around, about one or two inches off the fractured ends, break them off by easy blows over the *round* edge of the anvil, and the fibre will appear again. This experiment proves that a break, caused by sudden jars and intense vibration, may show a granular and even crystalline fracture, without having changed the molecular arrangement of the iron. All fibres are composed of mineral crystals, drawn out and elongated or flattened; and the fracture may be produced so as to exhibit in the same bar, and within the same inch of bar, either more fibre or more crystal. But a coarse crystalline bar will, under no circumstances, exhibit fibre; nor will a well worked out fibre exhibit coarse crystals.

My own view of this matter is, that a molecular change, or so called *granulation* or *crystallization*, in consequence of vibration or tension, or both combined, has in no instance been satisfactorily proved or demonstrated by experiments.

I further insist that crystallization in iron or any other metal *can never take place in a cold state.* To form crystals at all, the metal must be in a highly heated or nearly a molten state.

On the other hand, I am witnessing the fact daily, that vibration and tension combined will greatly affect the strength of iron *without* changing its fibrous texture. The cohesion and elasticity of wire and wire rope will be rapidly destroyed by great tension and vibration combined. Whether I shall be able to account for it or not, *there stands the fact.* But what is true of iron wire applies with equal force, and, when all circumstances and conditions are duly proportioned, with even greater force, to larger masses. The extensive opportunities which my pursuits offer, to make experiments and observations on wire and wire rope, authorize a positive expression on this subject. A great deal of fancy speculation has been indulged in of late years on this question of granulation and crystallization, but generally by men whose opinion can have no weight.

Now, while the fact remains that iron and steel will lose their strength by vibration and tension, it is proper to state, also, in this connexion, that this loss of strength bears a due proportion to the extent and duration of the vibration and tension. Wire ropes may lose their strength by three months service, *without* exhibiting much wear; and they may also last ten years, running all the time, and be greatly worn, before their strength is so far reduced as to be unfit to do duty. I will state here, that there are now ropes of my manufacture on the inclines of the Morris Canal, which have run nine years. This great durability is owing to comparative absence of vibration, in consequence of slow speed and good machinery, although a high tension is maintained.

The greater the elasticity and cohesion of the iron or steel, the better it will support vibration and tension, always provided, that the extent of this vibration and the amount of tension are kept within safe limits. Witness, as examples, the durability of watch-springs, piano wire, sofa and wagon springs, &c., &c., &c.

Wrought iron that has become brittle, as, for instance, chain, car axles, wire or wire rope, on being annealed, will have its softness and apparently, also, its strength restored. As far as softness is concerned, this is correct; but in regard to strength, when applied to wire or wire rope or to fine chains, it is a mistake. Soft annealed wire possesses only half the strength which hard wire has, and is without any elasticity. But wire rope without elasticity is worthless; very little work will make it brittle again and worse than before. It is different with heavy chains and with car axles. Made of indifferent material, crystalline or brittle when new, they will be greatly improved by an annealing process at the very beginning; and if this process is repeated from time to time, their lifetime may be prolonged. I maintain that a good car-axle, made of good material, and finished at the proper heat, by hammering or rolling, is stiffer and stronger than the same axle, when again subjected to annealing without hammering or rolling. Annealing restores softness, but at the same time reduces cohesion and elasticity. To restore the iron of a brittle car axle fully, can only be done by a full heat, with hammering or rolling, which of course will reduce its diameter.

The opinion prevails, that a well drawn-out fibre is the only sure sign of tensile strength. This, however, is true only when applied to *ordinary* qualities of bar or rail iron. The fact is different with good charcoal irons and with steel. The greatest cohesion is accompanied by a fine, close-grained, uniform appearance of texture, which, under a magnifying glass, exhibits fibre. The color is a silvery lustre, free from dark specks. The finer and more close-grained the texture, the nearer the iron approaches to steel. Those who are familiar with good Swedish or Norway irons, will support these statements. These facts alone should be sufficient to disprove the erroneous notion that good iron and steel, which should always be granular, will become so only by vibration, and will thereby lose their strength. But it is important to keep in mind the distinction between a fine uniform granular fracture, and a coarse crystalline fracture. Where coarse crystallization appears, there is a want of contact and compactness, consequently of cohesion and strength generally.

Wire cables, car axles, piston rods, connecting rods, and all such pieces of machinery, which are exposed to great tension as well as torsion and vibration, should be manufactured of iron which not only possesses great cohesion, but also a high degree of hardness and elasticity. The best car axles now in use, are those made of soft steel by Krupf, in Germany. This steel is manufactured from the spathic ore or natural steel ore, of the celebrated mines at Muessen in Siegen, Prussia. A correct report on these axles was given to me by one of the Prussian Commissioners of Railways, in whose district Krupf's works are located. They are safe in cold weather and seldom known to break. This proves that soft steel with more of a granular texture than fibre, possesses a much greater elasticity and strength than the best fibrous iron; and it also furnishes another strong proof against the granulation theory, so much credited in this country.

It may be objected that steel is a different metal from iron. But all irons and steels are only so many different alloys of the same metal. There is no essential difference between the two. What constitutes the true chemical and physical difference between the two varieties, is not so clear. The old idea, that steel owes its distinguishing properties to a greater per centage of carbon alone, is no longer maintained. There are not two metallurgists who agree as to the proper per centage of carbon that good steel ought to contain. The ablest chemists who have analyzed iron and steel, from Karsten and Berzelius down to the present day, have not been able to give us a correct analysis of these two metals. Mr. Mushet, Jr., has recently shown that the excellence of steel is depending upon the presence of Titanium, a substance formerly overlooked. But so long as the chemistry of iron and of steel is still without a sure basis, we must fall back upon well discerned empyrical facts.

The capacity of irons to resist vibration and tension differs much in different qualities, and still greater is this difference when the irons are exposed to a very cold temperature. The tubular bridge at Montreal will not last as long as one in Great Britian of the same dimensions,

material, and workmanship, and rendering the same service; and still less than the tubes over the Nile, in Egypt. One hard winter in Canada will be as trying to the structure as ten years are in Great Britain.

In order to examine the fitness of various qualities of iron for the manufacture of wire rope, I undertook, during the hard winter of 1856, at my establishment at Trenton, a series of experiments, when the thermometer was five to ten degrees below zero. The samples for testing, about one foot long, were reduced in the centre to exactly three-quarters of an inch square, and their ends left larger were welded to heavy eyes, making in all a bar of three feet long. Thus prepared, they were thrown outside of the mill, covered with snow and ice, and left exposed for several days and nights. Early in the morning, before the air grew warmer, a sample, inclosed in ice, would be put into the testing machine, and at once subjected to a strain of 26,000 lbs., the bar being suspended in a vertical position, left free all around. A stout mill-hand, armed with a billet of one-and-a-half inches in diameter and two feet long, then struck the sample horizontally a number of blows, hitting the reduced section, as hard as he could. The blows were counted and continued until rupture took place. Care was taken to maintain a tension of 26,000 lbs. during this test, by screwing up the lever, while the sample kept stretching. Other means for producing vibration were attempted, but none proved so effective as the hitting with an iron bolt. I would remark here, that most of these irons would support from 70,000 to 80,000 lbs. per square inch; and that good samples of three-quarters of an inch square, would support a strain of 26,000 lbs. for a whole week, with no visible stretching, provided all vibration and jarring was avoided. But the least jar would produce a permanent elongation.

Without going into the details of these interesting and instructive experiments, I will only state that the number of blows which the different samples resisted, when encased in ice, ranged from three to one hundred and twenty. Inferior qualities of a crystalline texture would break at the third or fourth blow. Good samples of refined puddled bar resisted very well, and went up to sixty blows, while the better qualities of hammered charcoal irons, supported up to one hundred and twenty blows, stretching and drawing all the time. Indeed, it seemed a wire-drawing process on a rough scale. On the tension being reduced to 20,000 lbs., some good samples resisted the almost incredible number of three hundred blows before breaking.

Such qualities of iron may be depended upon for the construction of wire cables and car-axles. They will be safe at the North Pole, while inferior qualities may answer very well in warmer latitudes.

Well observed facts of the durability of irons, when exposed to tension and vibration, are of more value than speculative opinions. I will here record a few more facts, experienced by myself.

In 1844 I removed the old timber aqueduct over the Allegheny river at Pittsburgh, the heaviest work of that description in the United States, consisting of seven spans of one hundred and fifty feet reach. It had stood fourteen years. All the suspension bars taken out of the

old trusses and arches, and originally made of good puddled iron, on being tested and worked up into bolts for the new wire suspension aqueduct, proved of good quality, as good as such irons generally are.

During the great fire at Pittsburgh, in 1845, the old Monongahela bridge, of eight spans, a heavy Burr structure, burned down. I contracted to put up a suspension bridge, and accepted all the old materials, which were not consumed, including about thirty tons of hammered charcoal iron of excellent quality. This iron, after a severe usage for over thirty years, was found so good that I had it all drawn into wire. Every bar was good for 60,000 lbs. per square inch, as strong and tough as it ever could have been before going into the bridge. The old structure was loose and limber, producing considerable vibration on all vertical bars.

On excavating for the southern anchorage between the old wing-walls of the old Monongahela bridge, a number of round bars of one-and-a-quarter inches diameter, about 40 feet long, good puddled fibrous iron was taken up. They had served as tie bars to keep the retaining walls from spreading. Screwed up tight, they had been under ground about twenty-five years, embedded in clay. The outside rust, firmly combined with clay and sand, appeared to have formed a protective coat. At any rate the strength of the iron had not suffered at all from oxidation, its quality was as good as any puddled bar manufactured at the present day.

Last year, while removing the old St. Clair Street Bridge over the Allegheny River at Pittsburgh, to make room for a new Suspension Bridge, since completed, I examined the old iron with considerable interest and care. All this iron had been manufactured about forty-one years ago, and had been the result of the first attempts at puddling ever made west of the Allegheny Mountains. The manufacturer, who is still living, informed me that in those days puddling was not well understood, and that, although the stock was good cold blast charcoal pig, the iron turned out of a highly crystalline texture. It proved so on its fracture, but of a good color, the texture was uniform and not coarse. On being heated and drawn down to half its size, it made a strong fibrous iron; all it wanted was work. There was not one fibrous bar in the whole lot of suspension bars; they were all alike crystalline and brittle in texture. This iron had, from the manufacturer's own testimony, undergone no change; it was as crystalline on the last day as it was on the first. But there was another quality of iron in the same structure. The straps and bolts which connected the chords with the posts and braces, had been manufactured of a good quality of hammered charcoal iron, and a most capital iron it proved after forty years service.

I will also draw attention to those interesting experiments made recently by Mr. Albert Fink, on a number of suspension bars, taken out of his bridges on the Baltimore and Ohio Railroad, for the purpose of testing their strength after seven years service. These tests exhibited a rate of strength which is only possessed by good iron, and led Mr. Fink to the conclusion that seven years wear had not affected the bars.

All irons form alloys of pure iron, mixed with carbon and other impurities. A certain amount of impurities in the shape of good cinder appears to be necessary to impart strength and cohesion to this metal, and also to make it malleable, and to give it welding properties. The purer the iron is, the higher the heat at which it will weld. Compare, for instance, good Swedish iron with common puddled bar. While the latter will weld at a low heat, the former requires a much higher heat. Compare their fracture and color. The good Swedish bar will exhibit either a fine granular appearance or fibre, accompanied by a silvery lustre, showing comparative purity; the puddled bar will be of a dark color, with a graphite lustre, and will show a coarse texture or loose fibre.

During the process of puddling, as well as of blooming, the melted pig-iron is mixed with cinder, and this mixture, which will adhere by cohesion, prevents the formation of large crystals, which is the tendency of pure iron in a molten state. Now by working (bringing to *nature*, as the puddler calls it), this mixing and crystallization is promoted. The subsequent squeezing and rolling of the puddled ball, or the hammering and shingling of the bloom, will have the effect of condensing, laminating, reducing, and drawing out these crystals, at the same time removing and squeezing out the superabundant cinder from between the metallic crystals. Thus the drawn-out fibre is composed of an aggregate of pure iron threads and leaves, enveloped in cinder.

Pure iron as well as very impure iron is weak; the maximum strength and toughness is obtained by a certain mixture of pure iron with carbon and cinder, thoroughly worked and incorporated. When the fibrous and laminar aggregation becomes so dense as to be fit for the manufacture of steel, then are by this very process sufficient impurities expelled, and the greatest degree of cohesion is obtained. Hence strong steel can only be made of strong iron, no matter what chemicals may be administered during the process.

Keeping the above process before our mind, we may now understand why even the best fibrous wrought iron, when exposed to long continued vibration under tension, or to torsion, bending or twisting, must inevitably become brittle, *because the iron threads and laminæ become loosened in their cinder envelopes.* But the cohesion between the iron and its cinder once destroyed, and its strength is gone. Now whether cohesion is the result of magnetic attraction (according to Faraday) or otherwise, this process appears to be purely mechanical. But let the explanation, which is here offered, be correct or not, the fact remains that fibrous iron and all kinds of iron and steel, will be rendered brittle by vibration and tension, or by bending and twisting, *without* undergoing any mysterious change in its molecular arrangement.

It is only within the last one hundred years that wrought iron has become a *necessity* on public and private works. Large structures entirely composed of iron are of a still more recent date. Long experience on a large scale is therefore wanting. But as far as it goes, the opinion is fully sustained, that good iron, not overtaxed by tension and vibration, and otherwise preserved, will prove one of the most durable building materials at our disposal.

The Menai Chain Suspension Bridge, has now stood about thirty-six years, and is still considered a safe work, although it has, for the want of stiffness, on several occasions suffered severely from gales. The old Wire Suspension Bridge, at Friburg, in Switzerland, has been in use about twenty-seven years, but it does not possess enough of strength and stiffness to guarantee its safety much longer in its present state.

It should be remembered that there are many suspension bridges in this country, as well as in Europe, built without any regard to stiffness, and are therefore constantly subjected to vibration, which must greatly limit their durability.

The cables of the Niagara Bridge, on the other hand, are free from vibration, consequently will last as long as the nature of good wrought iron will permit, when subjected to a moderate tension, not exceeding one-fifth of its ultimate strength. This durability I am unwilling to estimate at less than several hundred years.

Iron has emphatically become *the material of the age.* Upon its proper use the future comfort and physical advancement of the human race will principally depend. It will yet be the harbinger of peace, as already it has given us the means of locomotion and of intelligent intercourse. The subject of this paper is therefore of great importance and is entitled to a truthful consideration.

I will close this report by repeating once more, that the cables of the Niagara Bridge are made of a superior quality of material; that they possess an abundance of strength; that they are free from vibration; that they are well preserved and taken care of; and consequently that they may safely be trusted for a long series of years.

Trenton, N. J., August 1, 1860.

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*Water Cisterns in Venice.**

The French Academy of Sciences has received a communication from M. G. Grimaud, on the manner in which the Venetians construct their cisterns, a plan which he thinks might be advantageously introduced on the heights which overlook Paris, and are occupied by large establishments and a numerous population, and which would greatly benefit by them. Venice occupies a surface of 5,200,000 square metres (1300 acres), exclusive of all the great and small canals which intersect it. The annual average of rain is 31 inches, the greater part of which is collected in 2077 cisterns, 177 of which are public. The rain is sufficiently abundant to fill the cisterns five times in the course of the year, so that the distribution of water is at the rate of 16 litres (3½ gallons) per head. To construct a cistern after the Venetian fashion, a large hole is dug in the ground to the depth of about 9 feet, the infiltration of the lagoons preventing their going any deeper. The sides of the excavation are supported by a frame-work made of good oak timber, and the cistern thus has the appearance of a square truncated pyramid with the wider base turned upwards. A coating of pure and

* From the Journal of the Society of Arts, No. 405.

compact clay, 1 foot thick, is now applied on the wooden frame with great care; this opposes an invincible obstacle to the progress of the roots of any plants growing in the vicinity, and also to the pressure of the water in contact with it. No crevices are left which might allow the air to penetrate. This preliminary work being done, a large circular stone, partly hollowed out like the bottom of a kettle, is deposited in the pyramid with the cavity upwards; and on this foundation a cylinder of well baked bricks is constructed, having no interstices whatever, except a number of conical holes in the bottom row. The large vacant space remaining between the sides of the pyramid and cylinder is filled with well scoured sea sand. At the four corners of the pyramid, they place a kind of stone trough covered with a stone lid pierced with holes. These troughs communicate with each other by means of a small rill, made of bricks, and resting on the sand, and the whole is then paved over. The rain water coming from the roofs runs into the troughs, penetrates into the sand through the rills, and is thus filtered into the cylinder or well-hole by the conical holes already described. The water thus supplied is perfectly limpid, sweet, and cool.

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*A Subway in London.**

The Metropolitan Board of Works report that, with a view to the adoption of means for obviating the expense and inconvenience attending the breaking up of the pavement for the repair of mains and pipes, sewers, and other underground works, and in the hope of obtaining valuable data for their guidance in carrying out future improvements, they determined in making the New Covent-garden approach to form a subway under the street for the reception of gas and water mains, electric telegraph conductors, &c.; and on the 31st of July they entered into a contract for the execution of these works, and they are now in hand. They propose to construct under the street an arched subway 7 feet 6 inches in height by 12 feet in width, and also to form arched side passages for house service pipes, together with proper cellarage on each side of the street. In conjunction with the works proper sewers will be built, and convenient arrangements made for drainage.

* From the Lond. Civ. Eng. and Arch. Journal, Oct., 1860.

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*Strength of Building Stones.**

The following table (showing the specific gravity of colonial and other building stones, the force required to crush one-inch cubes, the amount of disintegration caused by the action of sulphate of soda, taking 1000 as an indication of perfect resistance, and the weight per cubic foot) is from Mr. Knight's treatise mentioned in our notice of the Melbourne Houses of Parliament:

* From the London Builder, No. 918.

	Specific gravity.	Crushing force per square inch.	Am't of disintegration.	Weight per cubic foot in an ordinary state.	Weight per cubic foot after four hours' immersion in water.
COLONIAL STONES.					
		In lbs.		In lbs.	In lbs.
Darley sandstone,	2350	2118	·800	124 7-16	132
Bacchus Marsh sandstone,	2213	1949	·200	124	133 5-16
Geelong sandstone,	2207	2150	·000	130 11-16	138 10-16
Kyneton sandstone,	2250	—	·600	131 7-16	135 11-16
Kilmore sandstone,	2423	3100	·650	—	—
Bulleen sandstone,	2484	2100	·750	142 9-16	147 4-16
Doncaster sandstone,	2487	3163	·800	—	150
Plenty sandstone,	2455	3200	·500	146 13-16	150 3-16
Portland (western district) limestone,	2503	3065	·700	—	—
Warrnambool limestone, a picked specimen, hardened by salt water,	2438	5035	·800	—	—
Cape Schank limestone,	2500	3550	·600	—	146
Ballan sandstone,	2446	2450	·800	—	—
Keilor sandstone,	2477	1600	·300	145 11-16	149 10-16
Western Port sandstone,	2357	5400	·400	148 8-16	149 5-16
Apollo Bay sandstone,	2473	Tested up to 6720 lbs. without producing any effect. The machine was inadequate to go beyond this weight.	1·000	—	—
Bluestone (basalt),	2625		—	—	163 7-16
Granite from the Plenty,	2655		1·000	—	—
Sienite from Gabo Island,	2652		1·000	—	—
Templestowe clay slatestone,	2600		1·000	—	—
Mount Sturgeon sandstone,	2386		1·000	142 12-16	144
INTER-COLONIAL STONES.					
Pitfield's New Kangaroo Point sandstone from Tasmania,	2207	2956	·900	132 3-16	134 9-16
Kangaroo Point stone, old quarry,	2252	2881	·050	135 5-16	137 2-16
North-west Bay sandstone from Quinn's quarry, Tasmania,	2322	2089	·700	140 9-16	143
Huon River sandstone, Tasmania,	2417	—	·001	—	—
Sydney sandstone,	2237	2228	·300	—	—
Adelaide sandstone,	—	2800	—	—	—
Adelaide marble,	2715	Tested up to 6720 lbs. without effect.	1·000	—	167 5-16
STONES FROM EUROPE.					
Fifeshire sandstones, Scotland,	—	1814	·100	128 3-16	136
Bath oolite, England,	2241	1600	·800	124 14-16	126 6-16
Portland oolite, England,	2447	3135	·950	137 2-16	140 9-16
Park Spring sandstone, from near Leeds, G. B.,	2383	Tested up to 6720 lbs. without producing any effect.	1·000	—	148
Caen, Normandy,	2076	1543	·700	134 5-16	136 4-16
Carara marble,	2713	Tested up to 6720 lbs. without producing and effect.	1·000	166	—

TABLE *showing the Weight required to crush inch cubes of the four Building Stones principally used in Melbourne.*

	Crushing force per square inch when dry.	Crushing force per square inch after four hours immersion in water.	
	In lbs.	In lbs.	
Pitfield's new quarry at Kangaroo Point,	2956	1919	31⅔
Pitfield's old quarry at Kangaroo Point,	2881	1428	50½
Darley,	2118	1260	35½
Bacchus Marsh,	1949	1073	45

The above results are derived from the average of four samples of each stone in a dry and two of each in a wet state.

Experiments to prove the fitness of the following stones to act as lintels, &c., tried on scantlings 4 by 4 inches, having a span of 4 feet, and the entire weight suspended from the centre:

	Breaking Weight. cwt.	qrs.	lbs.
Fifeshire, Scotland, sandstone,	1	1	26
Bath oolite, English,	2	2	20
Kangaroo Point white sandstone, from Pitfield's new quarry, Tasmania,	2	2	20
Kyneton, Victoria, sandstone,	2	2	21
Kangaroo Point sandstone, Pitfield's old quarry,	2	3	20
Bacchus Marsh sandstone, Victoria,	2	3	24
Darley sandstone, Victoria,	3	0	2
Bulleen sandstone, Victoria,	3	2	0
Doncaster sandstone, near Bulleen,	3	3	20
Geelong, Barrabool Hill, sandstone,	4	2	20
Portland limestone, English,	6	0	20
Park Spring sandstone, from England, near Leeds,	9	3	6
Adelaide marble,	10	1	11
Colonial basalt,	13	0	2
Mount Moriar, near Geelong,	4	3	15

For the Journal of the Franklin Institute.

Description of a New Portable Coffer Dam. By Capt. E. B. Hunt, Corps of Engineers, U. S. A.

[Read before the American Association of Science, at Newport, R. I., August, 1860.]

The use of the coffer dam in laying foundations under water, is among the best established and most reliable resources of the engineering profession, and its application in several classes of cases is well settled. In making studies for certain contemplated constructions at Fort Taylor, Key West, a new style of coffer occurred to me, which I hope soon to apply and which gives rational promise of success.

The first case considered was one of founding wharf and bridge piers on a rock bottom, over which a thin stratum of sand is spread. A set of piers, ten feet square, of solid masonry from the bottom, was first contemplated. For these the style of coffer planned was a strong square frame, with four corner posts, and a sufficient number of wale-courses across the four sides, and framed into these corner posts, to give the stiffness of side-wall necessary for supporting the whole water-pressure. The length of the corner pieces would be such as to give an excess of a foot or more at the top in the deepest water at high tide. The size in plan would have to be such as to give the requisite working space, and might be reduced to fifteen feet square. This frame work being put together, and stayed by a set of diagonal rope tie braces, could be launched and taken to its position, where it would be placed erect and adjusted to be level, using, if necessary, uprights in one or more angles, to bear on the bottom, or to be driven to the rock, and then lashed or bolted to the leveled frame. These angle posts can be sufficiently driven to give security against the force of tides and currents when needed, and also to sustain the weights required to be rested on the top of the frame. The coffer frame being thus fixed in

position, a row of sheet piling of sound, three-inch, hard pine plank remains to be driven to the rock, in contact with the wales, and guided either by two outside timber guides, made to be removable, or by fixed, flat, iron bar guides with the angles smoothed.

Now comes the feature which I suppose to be entirely novel, and which gives a peculiar character to this portable coffer dam. Take strong canvass, and proceed to make up a case or covering for the entire coffer, using two thicknesses of canvass, and interposing a complete coating of mineral or coal tar, so as not only to cause the two canvass layers to adhere to each other thoroughly, but to make a perfectly impervious sheathing. Along the bottom edge of the coffer sheathing, a similar double canvass flap is joined around the whole bottom line, which will lay spread out over the bottom as far as is judged necessary. This breadth of flap will depend essentially on the nature of the bottom. The surface to be thus covered should first be raked clear of sticks, stones, &c., to prevent tearing holes through the flap. The case and flap, water-tight through their whole extent, and having much positive strength to resist pressure, being put on the coffer and surrounding bottom, it only remains to proceed with the pumping, which being actively pushed will rapidly reduce the small enclosed water column. As this goes on, the exterior pressure comes first on the canvass coating, and this in turn rests against the sheeting piles and along the entire surface of the bottom. As the sheeting should be of even thickness with straight edges, the joints will be close and narrow; hence there will be no danger of ruptures from the bridging strain across them. The submerged exterior guides being either removed or formed of iron bars with beveled edges, would create no dangerous strains. To bring the flap more closely to the bottom, a sprinkling of sand or any clean earth might be thrown over it when in place, or the outer edge might be weighted if needful. In case the water should penetrate through the bottom covering layer, even from the outer boundary of the flap, it is only required to scoop out the enclosed sand, and fill in the bottom with a layer of concrete, as is usual in the common coffer, using the *tramis*, a plain wooden trough, or a box with a trip bottom.

It only remains to proceed in building the piers, using the top of the coffer as a platform, and to support the derrick or traveler, the materials being lightered alongside. Should a steam pump be found necessary, this could be worked on board a lighter, by using a flexible pipe, led through the side at the top, or it could be carried through the case and sheathing near the bottom. A series of lashings along the top of the case could be used for fastening it, and buoyed cords attached to the edge of the flap would serve for its manœuvre.

Another mode of treating this case might be preferred for great depths. This is by using a circular coffer made by trimming to the required arc sweeps of three-inch planks, combining them in full circle ribs so as to break joints and fastening with screw bolts. This is merely turning an arch centre into the vertical. Launching one rib, a set of upright struts with draw-bolts would be placed on it, and the second

rib built on them, &c. In some cases this might be superior to the square coffer. The modification of the case and flap would offer no serious difficulty. Various other timber and iron coffer frames might be advantageously used in treating this case.

In the instance first considered, it was desirable not to obstruct the water-way more than was necessary to get the solidity required by a permanent wharf for heavy vessels. A series of these piers giving the requisite supports for the wharf and bridge platforms answered these conditions, and it was supposed that this plan could be used in water of over twenty feet.

The facility with which this portable coffer can be struck and established is its great recommendation. Admit the water, hoist the case, draw the sheeting, and float the frame to its next station, buoying, if necessary, and then all becomes simple repetition. It is a question of judgment or calculation in each case to give the frame-work the stability required for resisting the pressures, currents, and wave actions; as also to decide where the probable violence of waves would make the plan impracticable or injudicious. Judgment must also be used in deciding whether the ruggedness of the bottom makes this plan inapplicable. Sometimes this difficulty would be fully met by throwing around the coffer a covering sheet of fine clay or marl, which will either make the bottom tight, or so cushion it that the flap can be used successfully. When we contrast the simplicity of this coffer and the facility with which it can be established and transferred, with the complex character of the ordinary fixed coffers, or with Stevenson's portable coffer, so limited, comparatively, in its applications and troublesome in erection, it will need but little consideration to perceive the utility of this device in numerous cases of bridge piers and other structures. To extend the above system to larger piers requires only the application of simple well established principles, which every competent engineer would easily make, and which need not be here dwelt upon.

It is likely to find its first application in a sea wall, which will probably be built at Fort Taylor next winter. It is proposed to use in this case a portable coffer of 50 by 12 feet in five compartments of framing, the intermediate submerged cross bars being made movable. The building of the first section of wall will not much differ from the building of a pier, except that the masonry bond at each end must be arranged to provide for the adjoining sections. In walls but little exposed to the sea, the sections can be brought above low water independently by building plain heads and leaving a clear joint. Of course this would not do where the foundation is bad and the load irregular.

To build this second section, the coffer would be re-established as before, except that the end should be arranged to embrace the wall already carried up, and the sheeting should be shaped to close in neatly on its front and rear faces. The case and flap will have to be so altered at this end as to fit the section of the wall, and extend along its front and rear faces for some distance. In the proposed wall, the use of dovetailed header and stretcher courses of granite is contemplated for the face, and a massive concrete filling for the back. The box planking for

the concrete can rest against the main uprights and can be recovered on striking, thus leaving all the spare space in the coffer for face work.

The simplicity of this coffer and the facility with which it can be shifted from section to section of a sea wall, lead me to believe that it will be found a great source of economy in constructing the walls of wharves, basins, docks, &c., when the shelter from waves and the character of bottom make it available. In many cases the flap could be nearly omitted, and in some rough bottoms the simple coffer case could be used and a slight foot slope of puddle or earth, which works tight, could be thrown in so as to serve the purpose.

This device not having yet been tried, I should scarcely bring it before the public, except that I am willing by publication at once to prevent patents and to give to engineers the benefits it offers, which can be seen beforehand with almost absolute certainty.

For the Journal of the Franklin Institute.

Expansion of Steam.

At a late meeting of the American Engineers' Association, New York City, the subjoined paper was read by its author, Mr. Louis Koch, Mechanical Engineer. E. B.

New York, Nov. 14, 1860.

QUESTION.— *What is the pressure of steam in the cylinder at the end of the stroke when cut off at half stroke?*

This question is easily answered by the experimental tables laid down by the Committees of the French and the Franklin Institutes, by Dr. Lardner, and many others, showing the total pressure in pounds, the corresponding temperature, the volume of steam compared to the volume of water that has produced it, and the mechanical effect of a cubic inch of water evaporated in pounds raised one foot; all of which show conclusively that the pressure of steam in the cylinder at the end of the stroke, when cut off at half stroke, is *not* one-half of its full pressure, and that this difference becomes greater, first, with the increase of pressure, and, secondly, with the decrease of cutting off; all this is strictly theoretical, without regard to friction or the influence of the atmospheric pressure.

The following are a few examples taken from Dr. Lardner's table:

Volume of Steam.	Temperature.	Pressure.	Double Volume.	Corresponding Pressure.	Difference.
1281	228·5	20 lbs.	2562	about 9½ lbs.	½ lbs.
2426	192·4	10 "			
679	269·1	40 "	1358	19·2 "	·98 "
1281	228·5	20 "			
470	295·6	60 "	940	28·03 "	1·97 "
883	251·6	30 "			
362	315·8	80 "	724	37·3 "	2·97 "
679	269·1	40 "			
295	332·0	100 "	590	46·34 "	3·36 "
554	283·2	50 "			

There can be no doubt of the existence of a fixed relation between the temperature and pressure of steam by immediate evaporation when it has received no heat except that which it takes from the water, but that relation is not known, and, therefore, empyrical formulæ have been proposed, which express, with more or less precision, this relation in different parts of the thermometrical scale.

Mr. Southern proposes the annexed, when the pressure does not exceed one atmosphere:—

$$P = 0{\cdot}04948 + \left(\frac{51{\cdot}3 + T}{155{\cdot}7256}\right)^{5{\cdot}13}$$

$$T = 155{\cdot}7256 \times \sqrt{P} - 0{\cdot}04948 - 51{\cdot}3$$

Tredgold proposes, when the pressure is from one to four atmospheres:—

$$P = \left(\frac{103 + T}{201{\cdot}18}\right)^6 \qquad T = 201{\cdot}18\ \sqrt[6]{P} - 103$$

Dulong and Arago propose, when the pressure is from four to fifty atmospheres:—

$$P = (0{\cdot}26793 + 0{\cdot}0067585\ T)^5 \qquad T = 147{\cdot}961\ \sqrt{P} - 39{\cdot}644.$$

Other formulæ are given by Biot, Taylor, Gay Lussac, &c.

The same uncertainty exists in the relation between the pressure and the augmented volume, and recourse has also been had to empyrical formulæ, of which two, as the most convenient for low pressure engines of every form as well as for high pressure engines on the expansion principle, are given.

Dr. Lardner proposes

$$V = \frac{3875969}{164 + P'}. \qquad V = \text{volume per number of cubic inches.}$$

A more accurate formula, when not less than 30 lbs. per square inch is used, is the following:—

$$V = \frac{4347826}{618 + P'}. \qquad P = 1 \text{ lb. per square foot.}$$

It is well to remark here, in relation to temperature, upon the well known fact that the sum of the sensible and latent heats is a constant quantity; if water at 32° temperature is converted into steam under a pressure of one atmosphere, or $14\frac{3}{4}$ lbs. per square inch, it is necessary to give it first 180° additional sensible heat, and afterwards 990° of latent heat, making a total of 1170° of imparted heat and 32° of contained heat, or 1202° in all. Should the pressure be two atmospheres, the sensible heat would be augmented to 250°, and the latent heat decreased to 952°; at three atmospheres, respectively $275\frac{1}{4}$° and $926\frac{3}{4}$°, and thus continuing, the sensible augmenting and the latent diminishing, as the pressure increases, the constant total being 1202° F., 1170° of which are necessary for the evaporation of ice-cold water, which, consequently, would be raised to the temperature of 1202° if evaporation was prevented.

A very easy mode of calculating the volume of steam under higher temperature than that of one atmosphere is the following:—

1. It being known that air expands with every degree Centigrade, to 1-270ths of its primitive volume at 0° C., it follows that 270 cubic feet of air when heated from 0° to 100° C., will expand to 370 cubic feet, and that 1 cubic foot of air of 100° C. heated with further (t) degrees will become

$$\frac{370+t}{370} \text{ cubic feet.}$$

2. It being known that steam expands agreeably to the same law, it follows that steam of 100° C. if its temperature is increased 21·4° C. will increase to

$$\frac{370+21\cdot4^\circ}{370} = \frac{391\cdot4}{370} \text{ cubic feet;}$$

therefore, steam from 1 lb. of water, or 1691 cubic feet, will have a volume of

$$\frac{391\cdot4}{370} \times 1691 = 1789\cdot078 \text{ cubic feet.}$$

3. And as it is, lastly, known that at the same temperature, the pressure of elastic fluids is proportionate to its density, and as saturated steam at 121·4° C. has just double the pressure (or that of two atmospheres), it follows that the before mentioned 1789·078 cubic feet must have double the density, and, therefore, a volume of 894·539 cubic feet.

Having now conclusively proved that the volume of steam increases with the pressure, it follows that there is a decrease of volume with the decrease of pressure, and it is, therefore, evident that the mechanical effect of steam when cut off at any part of the stroke will not be fully one-half of that of its expansion; all this is nothing new, as many tables have been laid down to this effect, as noted above, but as a basis for further calculations on the advantage or disadvantage of cut-offs generally they are valuable.

Now, let us see if there is an advantage in practice by cutting-off steam at any part of the stroke. We will select a bore of cylinder of 200 inches area, or about 16 inches in diameter and 6 feet stroke. We have, at first, to contend with friction and atmospheric pressure at the exhaust; the first of these (friction) is the most difficult to find a basis for, but it being generally conceded that $2\frac{1}{2}$ lbs. per square inch is sufficient in a well built engine, we will take that as a standard.

The atmospheric pressure at the exhaust is the same in both cases, and in relation to the quantity to be discharged, what is less in one case is made up by velocity in the other. It is to be remarked that when, according to the indicator, we work under 50 lbs. pressure, we actually have $64\frac{3}{4}$ lbs. on the piston (theoretically), the difference of pressure in the boiler and that exerted upon the piston, we will omit, being in both the same, if any, as has been asserted. Let us take 60 lbs. total pressure on the piston, and then find the mechanical effect

in following full stroke and cutting-off at one-half, one-third, and one-quarter stroke.

The mechanical effect of full stroke will be 60 lbs. per square inch, or 12,000 lbs. per 200 square inches, or .	72,000 lbs. lifted 1 ft.
Deducting for friction 2½ lbs. per square inch equals 500 lbs., or 3000 lbs. lifted one foot, and atmospheric pressure 14¾ lbs. per square inch equals 2950 lbs., or 17,700 lbs. lifted one foot . . . =	20,700 " "
and there remains a clear effect of	51,300 lbs. or 71¼ per c.

It has often been asserted that 85, 90, and 95 per cent. mechanical effect has been obtained, but this is decidedly an error, as the pressure was calculated agreeably to the indicator; the indicator in this case would only show 45¼ lbs. at 200 square inches equals 9000 lbs., or 54,300 lbs. lifted one foot, thus presenting a mechanical effect of nearly 94½ per cent., which is a deception.

The mechanical effect of cutting-off at one-half stroke will be 60 lbs. per square inch or 12,000 lbs. per 200 square inches; 3 feet stroke equals 36,000 lbs. lifted one foot; at the end of the stroke, as has been seen, we have 28·03 lbs. pressure, and, therefore, a mean pressure of 44·015 lbs. per square inch, or 8803 lbs. per 200 square inches; 3 feet stroke equals 26,409 lbs. lifted one foot; adding as above, we have 36,000+26,409 lbs.=62,409 lbs. lifted one foot. Deducting the foregoing friction and atmospheric pressure, 20,700 lbs. lifted one foot, and there remains a clear mechanical effect of 41,709 lbs. lifted one foot, or 57·93 per cent., with half the amount of steam, or 83,418 lbs. lifted one foot, with full steam, being nearly 116 per cent. (115·86 per cent.)

The mechanical effect of one-third stroke will be 60 lbs. per square inch, or 12,000 lbs. per 200 square inches; 2 feet stroke =24,000 lbs. lifted one foot; we have, as seen at the end of the stroke, 19·2 lbs. pressure, and, therefore, a mean pressure of 39·6 lbs. per square inch, or 7920 lbs. per 200 square inches; 4 feet stroke equals 31,680 lbs. lifted one foot; adding as above, we have 24,000+31,680=55,680 lbs. lifted one foot. Deducting friction and atmospheric pressure 20,700 lbs. lifted one foot, and there remains a clear effect of 34,980 lbs. lifted 1 foot, or 48·53⅓ per cent, with one-third the amount of steam, or 104,940 lbs. lifted one foot, with full steam, being 145¾ per cent.

The mechanical effect of one-quarter stroke will be 60 lbs. per square inch, or 12,000 lbs. per 200 square inches; 1½ feet stroke = 18,000 lbs. lifted one foot; at the end of the stroke, we will have 13·19 lbs. pressure, or a mean pressure of 36·595 lbs. per square inch, or 7319 lbs. per 200 square inches; 4½ feet stroke = 32,935·5 lbs. lifted one foot; adding as above, we have 18,000 + 32,935·5 = 50,935·5 lbs. lifted one foot. Deducting friction and atmospheric pressure, 20,700 lbs. lifted one foot, and there remains a clear effect of 30,235·5 lbs. lifted one foot, or nearly 42 per cent., with one-quarter the amount of steam; or 120,942·0 lbs. lifted one foot, with full steam, being 168 per cent.

Again; let us see if the same proportions exist in a smaller cylinder, shorter stroke, and the same pressure; we will select an area of 50 ins., or about 8 ins. in diameter, 4 ft. stroke, and 60 lbs. pressure.

1st. The mechanical effect of full stroke will be 60 lbs. per square inch, or 3000 lbs. per 50 square inches: 4 feet stroke . = 12,000 lbs. lifted one foot.
Deducting for friction 2½ lbs. per square inch = 125 lbs., or 500 lbs. one foot, and atmospheric pressure 14¾ lbs. per square inch = 737·5 lbs., or 2950 lifted one foot = 3,450 " "

And there remains a clear effect of . 8,550 " "
or 71¼ per cent.

2d. The mechanical effect of cutting off at half stroke, will be 60 lbs. per square inch, 3000 lbs per 50 square inches: 2 feet stroke = 6,000 lbs. lifted one foot.
44·015 lbs. mean pressure per square inch, or 2200¾ lbs. per 50 square inches: 2 feet stroke . . = 4,401½ " "

Adding, we have . . 10,401½ " "
Deducting friction and atmospheric pressure . = 3,450 " "

And there remains a clear effect of . 6,951½ " "
or 57·93 per cent. with half the amount of steam, and 13,903 lbs. lifted one foot, or 115·86 per cent. with full steam.

3d. The mechanical effect of cutting off at one-third stroke will be 60 lbs. per square inch, 3000 lbs. per 50 square inches: 1⅓ feet stroke = 4000 lbs. lifted one foot.
39·6 lbs. mean pressure per square inch, or 1980 lbs. per 50 square inches: 2⅔ feet stroke . = 5280 " "

Adding, we have . . 9280 " "
Deducting friction and atmospheric pressure = 3450 " "

And there remains a clear effect of . 5830 " "
or 48·58⅓ per cent. with one-third the amount of steam, and 17,490 lbs. lifted one foot, or 145¾ per cent. with full steam.

4th. The mechanical effect of cutting off at one-quarter stroke will be 60 lbs. per square inch, or 3000 lbs. per 50 square inches: 1 foot stroke = 3000 lbs. lifted one foot.
36·595 lbs. mean pressure per square inch, or 1829¾ lbs. per 50 square inches: 3 feet stroke . = 5489½ " "

Adding, we have . . 8489½ " "
Deducting friction and atmospheric pressure = 3450 " "

And there remains a clear effect of . 5039½ " "
or nearly 42 per cent. with one-quarter the amount of steam, and 20,157 lbs. lifted one foot, or 168 per cent. with full steam.

It only remains to investigate, if under a different pressure the relations will be the same: we will, therefore, take the same cylinders and strokes, with a pressure of 36 lbs.

1st. The mechanical effect of full stroke will be 36 lbs. per square inch, or 7200 lbs. per 200 square inches: 6 feet stroke . = 43,200 lbs. lifted one foot.
Deducting for friction 2½ lbs. per square inch = 500 lbs., or 3000 lbs. lifted one foot, and atmospheric pressure 14¾ lbs. per square inch = 2950 lbs., or 17,700 lbs. lifted one foot = 20,700 " "

Leaving a clear effect of . 22,500 " "
or 52·083 per cent.

2d. The mechanical effect of cutting off at one-half stroke will be 36 lbs. per square inch, or 7200 lbs. per 200 square inches: 3 feet stroke = 21,600 lbs. lifted one foot.
26·513 lbs. mean pressure per square inch, or 5302·6 per 200 square inches: 3 feet stroke . = 15,907·8 " "

Adding, we have . . 37,507·8 " "
Deducting friction and atmospheric pressure = 20,700·0 " "

Leaving a clear effect of . 16,807·8 " "
or 38·905 per cent. with one-half the amount of steam, and 33,615·6 lbs. lifted one foot, or 77·810 per cent. with full steam.

3d. The mechanical effect of cutting off at one-third stroke will be 36 lbs. per square inch, or 7200 lbs. per 200 square inches: 2 feet stroke = 14,400 lbs. lifted one foot.
23·48 lbs. mean pressure per square inch, or 4696 lbs. per 200 square inches: 4 feet stroke . = 18,784 " "

Adding, we have . . 33,184 " "
Deducting friction and atmospheric pressure = 20,700 " "

Leaving a clear effect of . 12,484 " "

or 28·9 per cent. with one-third the amount of steam, and 37,452 lbs. lifted one foot, or 86·7 per cent. with full steam.

4th. The mechanical effect of cutting off at one-quarter stroke will be 36 lbs. per square inch, or 7200 lbs. per 200 square inches: 1½ feet stroke . . . = 10,800 lbs. lifted one foot.
22·0178 lbs. mean pressure per square inch, or 4403·56 lbs. per 200 square inches: 4½ feet stroke . = 19,816 " "

Adding, we have . . 30,616 " "
Deducting friction and atmospheric pressure . = 20,700 " "

Leaving a clear effect of . . 9,916 " "

or 22·95 per cent. with one-quarter the amount of steam, and 39,664 lbs. lifted one foot, or 91·81 per cent. with full steam.

The same per centage exists under the same pressure, whatever the diameter of the cylinder or length of the stroke may be.

In the foregoing calculations, condensation in the cylinder has not been taken into consideration; it will, of course, be greater in proportion to the cut-off being smaller, but the difference to me seems to be trifling, and will cause but little alteration in the above calculations of per centage.

And now, having arrived at a point from which we are enabled to deduce certain elements, the subjoined are submitted:—

1st. The pressure of steam in the cylinder at the end of the stroke, when cut off at any point during the stroke, is smaller than the proportion to the full pressure; and this difference becomes greater, first, with the increase of pressure, and secondly, with the decrease of cutting off.

2d. The per centage of mechanical effect between that of full stroke and that of cutting off at any point of the stroke, remains the same, the cylinder being large or small, the stroke long or short, as long as the pressure is the same.

3d. The greater the pressure the greater the per centage of mechanical effect in high pressure engines, under all circumstances. (The relations seem to be different in low pressure engines, which I propose to discuss at a future time.)

4th. The greater the pressure, the greater the relative per centage between the full stroke and the cut-off system.

5th. There is no such thing as a greater mechanical effect in the same cylinder and at the same pressure, when cut-offs are used instead of full steam during the whole stroke; but, on the contrary, there is a proportionate and not inconsiderable falling off of mechanical effect when the former is used, notwithstanding all that has been or may be said to the contrary, and this difference becomes greater with a lesser pressure.

6th. The same amount of steam, under the same pressure, in the same cylinder, used with cut-offs instead of following full stroke, will produce a greater mechanical effect, but it requires a greater space of time; it being in the same proportion as the relative per centage between full stroke and cut-offs, or *vice versa*. During the same space of time, when cut-offs are used, and using a proportionate increase of pressure representing a greater volume of steam, the same mechanical effect will be obtained as that in following full stroke with a lesser amount of steam; or during the same space of time, and with the same amount of steam at a proportionate higher pressure, a greater mechanical effect will be obtained in using cut-offs as in following full stroke.

And now, allow me to remark, that here we have a full explanation of what has been asserted, that the mechanical effect in changing the full stroke to any part of the cut-off, during the working of the engine, was found to be greater in the latter case than in the former.

Suppose we have the same engine as that from which we drew our first deductions, *i. e.*, 200 square inches area, 6 feet stroke, and 60 lbs. pressure. Then we will have, as shown, a clear mechanical effect of 51,300 lbs., or 71¼ per cent. of the power exerted by the steam. I have further shown, that when the feeding of steam is cut-off at one-half stroke, we have a clear mechanical effect of 41,709 lbs., or 57·93 per cent., or with the same amount of steam used at full stroke, 83,418 lbs. effect, or 115·86 per cent. The fire or the production of heat not being changed in using the cut-off, it is evident that with each stroke of the engine, 4⅛ cubic feet of steam will be used less than before, the production remaining the same: and now let us take the steam space at 100 cubic feet, and the engine running only 12 revolutions per minute, and we have the startling result that, in less than one minute, the pressure in the boiler will be found to be at 100 lbs. per square inch, provided the safety valve be loaded to that amount; and its clear effect will be 83,300 lbs. lifted one foot, or 115·69 per cent., instead of 71¼ per cent. when full stroke was used. But when the safety valve remains loaded with 60 lbs. in working order, and its orifice is proportionate to the production of all the steam, then, gentlemen, there is no such thing as the engine beginning to jump, or attempting to "run away;" but, on the contrary, its speed will fall off almost immediately, until not more than 57·93 per cent. of the former 71¼ per cent. will remain.

7th. From the above deductions, drawn from calculations, we now arrive at the conclusion that a much greater mechanical effect is attained in using cut-offs instead of following full stroke, when the same volume of steam is used, or the same effect is attained with a lesser volume of steam: the consequence is, that the production of a lesser volume of steam, requiring a lesser quantity of heat, the same mechanical effect, in using cut-offs instead of following full stroke, is attained with a lesser amount of coal, all conditions being otherwise equal. Therefore, let me add, go ahead, busy inventors, and give us an improved cut-off, that will answer our purposes well, and give satisfaction to all.

MECHANICS, PHYSICS, AND CHEMISTRY.

For the Journal of the Franklin Institute.

Strength of Materials: Deduced from the latest experiments of Barlow, Buchanan, Fairbairn, Hodgkinson, Stephenson, Major Wade, U. S. Ordnance Corps, and others. By CHAS. H. HASWELL, Civil and Marine Engineer.

No. 2.

(Continued from page 343.)

TRANSVERSE STRENGTH.

The Transverse or Lateral Strength of any Beam, Rod, Bar, &c., &c., &c., is in proportion to the product of its breadth, and the square of its depth; and in like sided beams, bars, &c., it is as the cube of the side, and in cylinders as the diameter of the section.

When one end is Fixed and the other projecting, the strength is inversely as the distance of the weight from the section acted upon; and the strain upon any section is directly as the distance of the weight from that section.

When both ends are Supported, only, the strength is four times greater for an equal length, when the weight is applied in the middle between the supports, than if one end only is fixed.

When both ends are Fixed, the strength is six times greater for an equal length, when the weight is applied in the middle, than if one end only is fixed.

The strength of any rod, bar, &c., &c., to support a weight in the centre of it, *when the ends rest merely upon two supports*, compared to one *when the ends are fixed*, is as 2 to 3.

When the Weight or Strain is uniformly distributed, the weight or strain that can be supported, compared with that when the weight or strain is applied at one end or in the middle between the supports, is as 2 to 1.

In Metals, the greater the dimension of the side of a beam, &c., or the diameter of a cylinder, the less its proportionate transverse strength.

The strength of a *Cylinder*, compared to a *Square* of like diameter and sides, is as 4·71 to 8.

The strength of a *Hollow cylinder* is to that of a *Solid cylinder*, of the same length and quantity of matter, as the greater diameter of the former is to the diameter of the latter; and the strength of *hollow cylinders*, of the same length, weight, and material, is as their greatest diameters.

The strength of an *Equilateral Triangle*, having an edge up, compared to a *Square* of the same area, is as 22 to 27; and the strength of an equilateral triangle, having an *edge down*, compared to one, an *edge up*, is as 38 to 23.

NOTE.—In these comparisons the beam or bar is considered as one end being fixed, the weight suspended from the other. In Barlow, and other authors, the comparison is made when the bar or beam rested upon supports. Hence, the stress is contrariwise.

Detrusion is the resistance that the particles or fibres of materials oppose to their sliding on each other, under a detrusive strain. Punching and shearing are detrusive strains.

Deflection.—When a beam, bar, &c., &c., is deflected by a cross strain, the side of the bar, &c., which is bounded by the concave surface is *compressed* and the opposite side is *extended.*

The *Neutral Line*, or *Axis of Equilibrium*, is the line at which extension terminates and compression begins.

In Stones and Cast metals, the resistance to compression is greater than the resistance to extension.

In Woods, the resistance to extension is greater than the resistance to compression.

The general law regarding deflection is, that it increases, *cæteris paribus*, directly as the cube of the length of the rod, bar, &c., and inversely, as the breadth and cube of the depth.

The *Resilience* or toughness of a body, is a combination of flexibility and strength.

The resistance of *Flexure* of a body at its cross section is very nearly nine-tenths of its tensile resistance.

Relative Stiffness of materials to resist a transverse strain:—

Wrought Iron,	1·3	Oak,	·095
Cast Iron,	1·	Ash,	·089
White Pine,	1·	Beech,	·073
Yellow Pine,	·087	Elm,	·073

The strength of a Rectangular Beam in an *Inclined position* to resist a vertical stress, is to its strength in a horizontal position, as the square of radius, to the square of the cosine of elevation; that is:—as the square of the length of the beam, to the square of the distance between its points of support, measured upon a horizontal plane.

Beams of cast metal, having small dimensions, are stronger *pro rata* than those having larger dimensions, in consequence of their having a greater proportion of chilled surface compared to their elements of strength resulting from dimensions alone.

Experiments upon bars of cast iron, 1, 2, and 3 inches square, give a result of 447, 348, and 338 lbs., respectively; being in the ratio of 1·, ·78, and ·756.

The strongest rectangular beam that can be cut of a cylinder, is one of which the squares of the breadth and depth of it, and the diameter of the cylinder, are as 1, 2, and 3, respectively.

TABLE OF THE TRANSVERSE STRENGTH OF MATERIALS: Deduced from the experiments of U. S. Ordnance Department, Barlow, Rennie, Stephenson, Hodgkinson, Fairbairn, Pasley, Hatfield, and the Author, and reduced to a uniform measure of *One Inch Square, and One Foot in Length; Weight Suspended from one end.*

MATERIALS.	Specific gravity.	Breaking weight.	Weight borne while the elasticity was perfect.	Value of W for general use.
Woods.				
Teak,	·745	206 lbs.	65·5 lbs.	60
Oak, English	·934	140	43·8	35
do superior	·748	188		45
Canadian	·872	146	49·5	36
American do		230		50
Dantzic	·756	122	43·8	30
African	·982	208		50
Ash,	·760	168	49·5	55
Beech,	·696	130	33·	32
Birch,	·711	160		40
Elm,	·553	82	27·5	25
		170	45·	40
Pitch Pine,	·660	136	33·	45
American	·777	160		50
White Pine,	·553	92	33·	30
American		130		45
Riga Fir,	·753	94	27·5	30
Norway Pine,	·577	123	44·	40
Locust,	·936	295		100
Deal, Christiana	·698	137		45
Larch,	·556	93	33·	25
White wood,		116		38
Maple,		202		65
Hickory		250		55
Chestnut		160		53
Riga Fir, Wet	·632	107		30
Dry	·330	96		30
Metals.				
Cast Iron, American, means of five divisions of grades.	7·087	507		125 to 160
	7·182	632		155 210
	7·246	733		180 240
	7·270	762		190 250
	7·340	772		192 250
Mean by Maj. Wade	7·225	681		170 225
West Pt. Found. extreme		980		250 325
English,—Low Moor Cold blast	7·055	472		
Gartsherrie, Hot "	7·017	447		110 140
Carron, Cold "	7·094	443		
Muirkirk, Hot "	6·953	418		
Ponkey, Cold "	7·122	581		145 190
Hot blast, mean		500		125 165
Cold " "		516		130 170
Ystalyfera, cold blast		770		195 255
Mean of 65 kinds,		500		125 165

Materials.	Specific gravity.	Breaking weight.	Weight borne while the elasticity was perfect.	Value of W for general use.
Metals (Continued).				
Steel, greatest	7·862	1918		400 to 500
		Permanent bend.		
Wrought Iron		700		
American	1500	650		160 210
		600		
English	1000	400		100 130
"	1080	520		130 170
"	1200	550		135 180
Swedish*		665		165 220
English, the stress applied horizontally,		set. ·001 in.		180 240
		190		
Mixture of Cast and Wrought Iron, &c.				
Cast Iron, Blaenarvon	575			145
do 10 pr. ct. of wrought	703			175
20 "	842			210
30 "	920			230
40 "	767			195
50 "	727			185
and 2½ per cent. of Nickel,	693			173
mean	750			188
Stirling, 2d quality	623			154
3d "	499			125
Stones (American).				
Flagging, Blue	2·707	31·		
Freestone, Little Falls, N. Y.,	2·326	24·		
Belleville, N. J.,	2·300	20·1		
		17·8		
Connecticut	2·462	13·		
Dorchester	2·289	10·8		
Aubigny,	2·472	9·3		
Caen	2·218	6·1		
Granite, blue, coarse	2·604	18·		
Quincy, Mass.,	2·658	26·		
Stones (English).				
Yorkshire Blue Stone,		26·		
Paving,		10·4		
Landing,		22·5		
Caithness Paving, Scotland		68·		
Valentia do., Ireland		68·5		
Welsh do.,		157·		
Arbroath,		17·		
Craigleith Sandstone,	2·266	10·7		
Hailes,		7·4		
Felling,		7·5		
Kentish Rag,		35·8		
Cornish Granite,		22·		
Portland Oolite,	2·145	21·2		
Bath,		5·2		
Bangor Slate,		90·		
Llangollen do.,		43·		

* With 840 lbs. the deflection was 1 inch, and the elasticity of the metal destroyed.

Concretes (English).	Breaking weight.
Aberthaw lime 1, gravel 7,	·8
Hydraulic lime and gravel (old),	2·
Fire brick beam, Portland cement,	3·1
do, sand 3 parts, lime 1 part,	·7
Cements (English).	
Portland,	37·5 30·4 10·2
do 1 part, sand 2 parts,	10·
Blue clay 5 parts, chalk 4 parts,	14 3 5·8
Blue clay and chalk,	5·4
Sheppy,	5·
Bricks (English).	
Fire brick,	14·
Stock brick, well burned,	5·8
do inferior burned,	2·5
Old brick, / New " / Best stock, — English,	9·1 10·7 11·8

Comparative Transverse Strength of a Prism of Lime and Cement mixed with various preparations of Gravel and Sand (Sir C. W. Pasley).

One Inch Square, and One Foot in Length, the Weight being Suspended from one end.

Mixture.	Days immersed in water.	Age in days.	Breaking weight.
Chalk lime 1, Sand 3·25,	19	396	·81 lbs.
do 1, Gravel 3, Sand 4,		446	·156
do 1, Gravel 6, Sand 3,	32	446	·39
Halling lime 1, Sand 3,		342	1·40
do 1, Gravel 4, Sand 2,	18	457	1·62
do 1, Gravel 6, Sand, 3,	32	453	1·43
Blue Lias lime 1, Gravel 6, Sand 3,		345	·80
Rosehill lime 1, Sand 2,		342	1·56
Sheppy and Harwich Cements 1, and Gravel 1·5, Sand 2·0,		385	·93
Chalk 5, Blue clay 2, — Gravel 1·5, Sand 2·0,		385	·156
Chalk 5, Blue clay 2, — Gravel 5, Sand 2,		439	·41
Chalk 5, Blue clay 1, — Gravel 3, Sand 4,	18	431	·76
Chalk 5, Blue clay 1, — Gravel 6, Sand 2,	18	431	1·03
Chalk 6, Blue clay 1, — Gravel 5, Sand 4,	16	429	·45
Chalk 7, Blue clay 1, — Gravel 5, Sand 4,	16	429	·44
Chalk lime 1, Screened ballast 5,		270	1·12
do 1, do 10,		256	·27
Halling lime 1, do 3,		270	1·40
do 1, do 10,		270	·42
Blue Lias lime 1, Ballast, 6,		239	1·08
do 1, do 10,		268	·33
Sheppy & Harwich Cements 1, do 2,		143	1·04
do 1, do 7,		234	·12

TABLE OF THE TRANSVERSE STRENGTH OF CAST IRON BARS AND OAK BEAMS OF VARIOUS FIGURES,

Having a Uniform Sectional Area of One Square Inch, One Foot in Length, Fixed at one end, Weight Suspended from the other.

	FORM OF BAR OR BEAM.		BREAKING WEIGHT.
Cast Iron.		Square, . . .	673 lbs.
		do, diagonal vertical, . .	568
		Cylinder, . . .	573
		Hollow Cylinder, greater diameter twice that of less,	794
		Rectangular, 2 ins deep × ½ in. thick, .	1456
		do 3 " × ⅓ " .	2392
		do 4 " × ¼ " .	2652
		Equilateral triangle, an edge up, .	560
		do, an edge down, .	958
		2 ins. deep × 2 ins. wide × ·268 ins. thick,	2068
		" " " .	555
Oak,		Equilateral triangle, an edge up, .	114
		do, an edge down, .	130

TABLE OF THE TRANSVERSE STRENGTH OF SOLID AND HOLLOW CYLINDERS OF VARIOUS MATERIALS,

One Foot in Length, Weight Suspended from one end.

MATERIALS.	Specific gravity.	Solid external diameter in inches.	Hollow internal diameter in inches.	Breaking weight in lbs.	Breaking weight for 1 inch external diameter, and proportionate internal diameter.
WOODS (English).					
Fir,* . .	·588	2·		772	97
Ash, .	·590	2·		685	86
" . .	·580	2·	1·	604	75
" .	·601	2·	·75	625	78
" . .	·586	2·	·50	636	79
White Pine, American		1·		75	75
"		2·		610	76
METALS.					
Cast iron, cold blast		3·		12,000	444
STONE WARE.					
Rolled pipe of fine clay.		2·87	1·928	190	8

*An inch square batten from the same plank as this specimen, broke at 139 lbs.

RESULT OF EXPERIMENTS ON THE TRANSVERSE STRENGTH OF SCARPHED BATTENS (BARLOW.)

Battens 4 feet in length, Fixed at One end, and Loaded at the other.

[*Note.*—Dimensions of battens not given.]

Scarph, 12 inches in length, small end up, and one inch from face of fulcrum, .	Broke in the neck of the scarph, close to the fulcrum,	87 lbs.
Scarph, 12 inches in length, large end up, and one inch from face of fulcrum, .	Fastenings of small end of scarph drew out, .	101
Scarph, vertical, .	Broke in the scarph, .	211

(To be Continued.)

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*The Cylindrical Spiral Boiler.** By JOHN ELDER.

The object of the construction of this boiler is to obtain a form with all the useful properties of the simple cylindrical high-pressure boiler on shore, adapted to steamships. The following advantages appear to be attained over the ordinary marine boiler, namely:

1. A form of boiler capable of carrying higher pressure and presenting more heating surface, and of a more effective description, from a given weight of material.
2. A boiler capable of being easier cleaned and repaired in both water and fire spaces.
3. A boiler capable of producing superheated steam to any practical temperature.
4. A less average specific gravity of water whilst working at sea with the usual amount of feed and blow-off, and a more perfect combustion-chamber, and better formation of flue surface.
5. The pressure being altogether internal, it is not liable to collapse, a danger lately ably demonstrated by Mr. Fairbairn; and as the diameter of the various cylinders are reduced to the minimum size for permitting the tradesmen to pass through, clean and repair them, the boiler when formed of ordinary thickness possesses enormous strength without stays.
6. The expense of the boiler per square foot of heating surface is about the same as the ordinary boiler, and is capable of carrying five times the pressure.

The general construction of this boiler is as follows:—There are twenty-four round boilers or tubes, of not less than 19 inches diameter each, twenty-two of these forming, when bound together, a cylindrical vertical shell; the twenty-third, a centre boiler concentric to that shell; and the twenty-fourth, a spiral coil-boiler winding spirally round

* From the London Civ. Eng. and Arch. Jour., September, 1860.

between the centre boiler and those composing the circumference shell. These boilers contain the water, and the spaces between them the fire.

The feed-water passes first into the spiral compartment, or No. 24, and from it into the centre compartment, or No. 23, and into each in rotation, and blows off at the last compartment, or No. 1, thus rendering the water in No. 24 nearly pure sea-water, and gradually from compartment to compartment more dense, till it blows off at No 1 at the usual density, and thus makes the average specific gravity of the water less than usual.

The twenty-two outside boilers are 24 feet long, 19 inches diameter, and $\frac{5}{16}$-inch thick; the bottom ends are conical for 3 feet, and knee'd outwardly to give a larger diameter of furnace, say 12 feet diameter. There is a furnace door for every alternate tube, or say 11 furnace doors, equally divided round the base of the boiler, giving great facility to the firemen for doing their work efficiently. In firing it is proposed to charge all the fresh coal round the circumference of the fire, in order that the hydrogen of the coal may be consumed separately from the carbon; and as the furnace has great altitude, the combustion will be completed in vertical flames from the coals, and will thus prevent the carbonic acid gas given out from the combustion of the carbon coming so much in contact with and preventing the combustion of the hydrogen, as is usual in ordinary furnaces.

The centre compartment, or No. 23, is 30 feet long, 34 inches diameter, and $\frac{3}{8}$-inch thick, with 3 feet at the bottom and top conically reduced to 18 inches diameter, forming a man-hole door; the upper end of this vertical tube forms a reservoir for the steam of the whole twenty-four compartments, and acts as a superheating apparatus, and may be carried up the funnel to the extent necessary to superheat the steam to 400°. The steam-pipe is taken from the top of this boiler to the safety-valve chest, fastened on the front of the boiler low down, which serves as a water-trap during the discharge from the safety-valve chest, the steam-pipe to the engines being taken off the same pipe at a higher level than the escape steam. The spiral compartment, or No. 24, is about 100 feet long, 34 inches diameter, and $\frac{3}{8}$-inch thick, made of the best iron boiler-plate; the ends are conical for 3 feet formed into man-hole doors; this spiral boiler makes four or five convolutions close round the centre one, and is bound close to the circumferential boilers by hollow stay-bolts, and fastened to the centre one at each end only; in the same manner the steam and water flows through the whole boiler by these hollow bolts or rivets, and completes the entire circulation of water and steam. The whole of these 24 compartments or boilers terminate at the bottom about 1 foot below the fire-grate, and are supported on six stanchions from the ash-pit beneath, making a free passage for the air under the grate bar; the circumferential compartments or boilers terminate at the top 6 feet above the ship's deck, and have each a man-hole door forming the cover; the funnel is made conical at the bottom to embrace the internal diameter of the boiler shell and draw off the smoke in the usual manner. This completes the whole boiler proper, but in order to prevent radiation of heat,

a thin outer casing of iron is made (9 inches) clear of the boiler all round, terminating about 7 feet from the stoke-hole floor; and above, at the level of the galley or funnel-house, this casing is lined with felt and thin wood, to keep the deck and the adjacent parts cool and retain the heat. The twenty-two straight cylindrical boilers or compartments are constructed in the sides by four plates 24 feet long and 16 inches broad, rolled to a 9½-inch radius curve at the iron works, leaving no plate-setting for the boiler-maker of this description.

The plates of boiler No. 24, or the spiral compartment, are delivered flat by the iron-maker, and are bent to the spiral curve by one blow of a large spiral concave block falling upon a counterpart convex one, prepared by the constructors of the boiler. This operation has been found to simplify the making of this spiral cylindrical boiler to about the same amount as the straight cylindrical boilers. The conical ends are bent in the same manner as the spiral plates, and the whole work of plate-bending reduced as far as possible to machine work. The products of combustion, after leaving the furnace, have to travel spirally upwards a distance of 100 feet, and must of necessity be continually rotating during that time, and prevent the possibility of any portion passing off without being brought frequently in contact with the heating surface of the boiler, and will therefore be cooled down to the minimum temperature compatible with a given amount of cooling surface, or the greatest quantity of heat extracted from the products of combustion before their escape to the atmosphere.

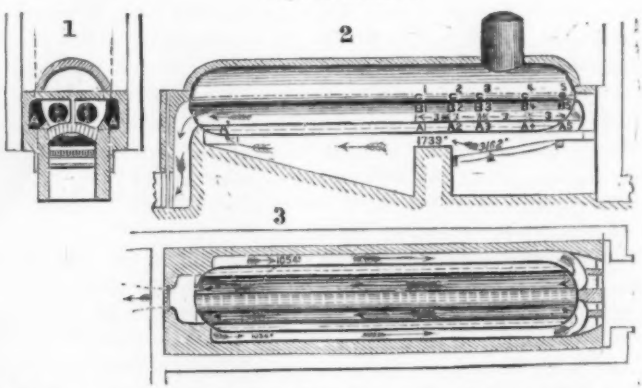
This spiral coil and all the heating surfaces will keep more clear of flue-dust than usual, and will consequently be more efficient in that respect, as well as save the usual trouble and loss by spunging experienced in the ordinary tubular boilers at sea. Also, as the products of combustion must pass off at the rate of at least 7 feet per second, in this as in ordinary boilers, it will take upwards of 14 seconds from the time it leaves the furnace till it arrives at the top of the boiler; whilst if the boiler were of the ordinary tubular type it would pass in about two seconds along the whole heating surface of the boiler; the gas has, therefore, seven times more time to give out its heat, and its revolving tendency will not admit of the same stratum of gas passing along the passages after it is cooled down, as is the case with the ordinary boiler, but will bring the hot products of combustion usually occupying the centre of the tubes of a tubular boiler into contact with the cooling surfaces, and reduce the whole products of combustion to one temperature before entering the chimney.

In cleaning the salt or sludge out of these boilers the man and sludge hole doors are taken off the top and bottom (and the hose of fresh water may be played down through from the top, and the refuse run out at the bottom). The man in charge can also pass down through the whole boiler; the dimensions necessary for this purpose being made the minimum and maximum of the various compartments of the boiler; and are specially constructed to maintain to the engines steam at a much higher pressure than usual, in order to admit of a much larger amount of expansion to be developed by the engines, which are all on

the double cylinder expansive principle. The constructors are now making the boilers for three steamships on this principle, two of which are for carrying Her Majesty's mails on the Pacific between Valparaiso and Panama (as described by the writer at the meeting of the British Association at Leeds); and it has long been his desire to be able to construct boilers for marine purposes without stays, and with no surface exposed to the collapsing tendency, which in so many cases has been the cause of loss of life aboard of steam-ships. The boilers now described have no large flat surfaces and no stays, the whole tendency of the pressures being to inflate the boiler plates, and, if possible, to give them a stronger form; the smallest diameter is large enough to give access to the men in charge, and the largest diameter is 34 inches, and $\frac{3}{8}$-inch thick,—dimensions that can carry several hundred pounds pressure on the square inch before rupture could take place. Such a form the writer adopts with great satisfaction to himself as a constructor sending machinery abroad, where the usual form of boiler gives him considerable anxiety. In comparing the construction of this boiler with that of the ordinary tubular one, in the latter angle-iron ribs and stays now compose a large portion of the weight and expense; contribute no heating surfaces; and if one stay breaks, which is no uncommon occurrence, the next is placed in great danger, and if it gives way the whole may follow in rotation and a serious accident be the result. In the former boiler, however, the plates may be reduced to a very small amount of thickness by tear and wear before explosion could be expected.

Having thus described the objects of the spiral boiler, it might not be out of place to give the following statement of the comparative evaporative power and temperature of the gases in the furnace and chimney of the spiral boiler, with three of the ordinary types of boiler now in general use.

Figs. 1, 2, and 3.



The three types experimented upon, were, first, a common cylindrical land boiler (Figs. 1, 2, and 3), 33 feet long, 5 feet 6 inches diameter, with two round flues 19 inches diameter through the centre; this boiler had 40 feet of heating surface to the nominal horse-power

of the engine; the two flues contained 20 feet, and the shell 20 feet per nominal horse-power; the furnace was below the boiler at the fore end, had a fire-grate of 26 square feet, the fire passed underneath the boiler to the opposite end from the furnace, and returned along the sides, and then passed back again through the flues to the chimney. The temperature above the centre of the fire was found to be, on one occasion, 3200°; at the top of the bridge 1730°; the temperature of the gases gradually reduced as they passed back the remaining length of 26 feet under the boiler and along the side flues, till they entered the flues at 1163°, and left them at 800°. Thus the furnace containing a surface of 2 feet per nominal horse-power reduced the heat about 1500°, the shell of the boiler behind the furnace of about 18 feet per nominal horse-power reduced the temperature about 600°, and the flues containing a surface of 20 feet per nominal horse-power reduced the temperature about 350°. The temperatures of the gases in the flues were found to be about the same in the centre as at the top; but at the bottom of the flues, the temperatures of the gases were at the fore-end rather less than at the top, but towards the back-end the temperature of the bottom of the flues reduced gradually below the temperature at the top to the extent of 300°. Upon another occasion the temperature over the centre of the fire was found to be 3610°; at the top of the bridge 1739°; and the different temperatures of the flues were as indicated in Fig. 2, where the average temperatures of the flues at B^1=826°, B^2=879°, B^3=937°, B^4=959°, and at B^5=981. The temperatures at the top of the flues at C^3=982°, C^4=1034°, C^5=1087°. The temperatures at the bottom of the flues at A^1=571°, A^2=603°, A^3=678°, A^4=764°, A^5=822°. It would therefore appear that, notwithstanding the large amount of surface in this boiler, the evaporative power is very inferior, as the amount of heat taken out of the gases per square foot of heating surface is very small; and the natural conclusion is that the gases pass along in straight lines, and only the thin strata in contact with the surface is cooled down. In the results of the spiral boiler (Fig. 6) three times the quantity of heating surface was found to reduce six times the quantity of gas from the same temperature of 3200° to a temperature of 480° instead of 800°, showing that a more complete turning over of the gases is much wanted in our land boilers. The water evaporated per hour in the land boiler referred to was found by meter to be 2000 lbs., and the coal, best Glasgow quality, found to be 300 lbs. per hour; making about 6½ lbs. of water per pound of coal. During the measurement of the water evaporated by the meter, indicator diagrams of the engine were taken with a view to calculate the weights of steam by the ordinary method, and the calculations were found to agree with the meter; these calculations can be repeated and substantiated at any time.

The second type of boiler tested was that of the ordinary steamboat horizontal tubular boiler (Fig. 4); the example chosen was one in a first-class ocean steamer. The temperature of the furnace was found to be 3200°, and the inside of the funnel about 1100°. The heating surface of this boiler was 22 feet per nominal horse-power, and

the water evaporated about 8½ lbs. per pound of coal according to the calculations from the diagrams. The coal consumed was about 20 lbs. per square foot of fire-grate, of the best Glasgow coal.

The next example taken was that of a first-class vertical tubular boiler (Fig. 5), on Mr. David Napier's principle, now universally liked on the Clyde for river steamers. This boiler had a surface of about

Fig 4.

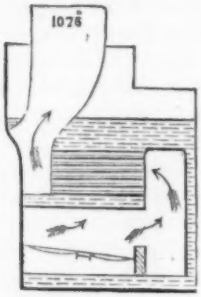
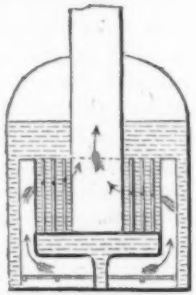


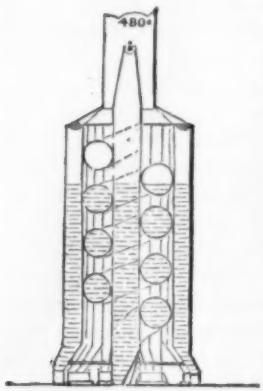
Fig. 5.



22 feet per nominal horse-power; the temperature of the fire was found to be about 3300°, and in the funnel 1160°; the weight of water evaporated was found by calculation to be 8¾ lbs. per pound of coal consumed, and the rate of combustion about 20 lbs. per square foot of fire-grate.

In the spiral boiler (Fig. 6) of the *San Carlos*, *Guayaquil*, and *Prinz van Orange*, the boilers were found to give the following peculiar results:—1st, that even with Scotch coal there was no smoke emitted from the chimney, and no carelessness on the part of the fireman seemed to effect the formation of smoke; 2d, that the boilers showed a bright furnace, indicating first-class draft; the temperature of the funnel was found to be 480° while the fire was at its greatest energy. The heating surface was, in the case of the *San Carlos* and *Guayaquil*, 2200 square feet, the coal consumed 1400 lbs. per hour, and the water evaporated 11 lbs. per pound of coal consumed; the fire-grate contained about 76 square feet, and the rate of combustion about 20 lbs. per square foot of fire-grate. The heating surface of the boiler was 18 feet per nominal horse-power; the coal consumed was Glasgow best steam coal. The stoke-hole was found to be remarkably cool, and the boiler, which was loaded to 52 lbs. on the square inch steam pressure, and tested to 150 lbs. on the square inch water pressure, was found to be perfectly tight. In the case of the *San Carlos*, I may mention that the ship has now steamed about 20,000 miles, and has not been in any port more than three days; during that time she has been consuming soft Chili coal for a

Fig. 6.



considerable part of her voyage, and the merits of the long flue show a decided advantage in this boiler over the ordinary tubular boiler for the native bituminous coal of South America.

In order to give in a more extended form the comparative evaporative power of various flue and tubular boilers, the writer begs to lay before the Association the accompanying table. It shows several proportions of heating surface and evaporative power of several ships that have come under his notice. He can certify the accuracy of most of these particulars, except that shown in the last column, which is taken from Professor Rankine's report on the performance of the *Thetis*. This vessel has about six times more heating surface in her boilers in proportion to the coal consumed than any example the writer is aware of. The boiler is Craddock's patent boiler, though that inventor's name appears rarely to be mentioned in connexion with the said vessel. Efficient, however, as this boiler must be as an evaporator, it cannot possibly accomplish the quantity shown in the table.

Comparisons of certain Results obtained from Certified Diagrams of Steamers.

	Elk.	Earl of Ab'rd'n.	Valparaiso.	Pride of Erin.	Inka.	Europa.	Camb'n.	Thetis.
Nominal horse-power,	250	380	320	400	80	648	472	80
Ind cated "	780	780	826	960	272	1207	1072	226
Propor'n of indicated H.P. to nominal ditto,	3·28	2·05	2·581	2.4	3·8	1·863	2·272	2·82
Diameter of cylinder,	57 in.	70 in.	{Two 52 / Two 90}	72	{Two 28 / Two 48}	90	77·5	{One 21 / One 42}
Length of stroke,	5 ft. 6 in.	6 ft.	5 ft.	5 ft. 6 in.	3 ft.	8 ft.	7 ft. 6 in.	2 ft. 6 in.
No. strok·s per minute,	25	17·5	24	22	32	15½	16	52
Boilers—flue or tubular,	Tubular.	Flue.	Flue.	Flue.	Flue.	Flue.	Flue.	Craddock's Patent.
Area of fire-grate,	144 ft.	190	130	252	50	314	247	
Area of heating surface,	4000	4300	2400	4400	480	7000	5400	Ab't 4000
Coals consumed per h.,	3360 lb.	3584	2520	4928	672	5100	4480	226
Quality of coal,	Glasgow best.	Newcastle.	Welsh.	Welsh.	Welsh.	Welsh.	Welsh.	Good.
St. ev't·d per lb. of coal,	7·354	6·87	7·74	7·159	8·1	7·7	7·569	Ab't 15 lb.
Estimate, water ev'ted,	8·1	7·4	8·6	7·9	9·0	8·5	8·3	18 lb.
Coal consumed per I.H.P.,	4·071	4·385	3·05	5·126	2·47	4·2	4·17	1·018
Fire-grate per nom. H.P.,	·576	·5	·406	·63	·625	·484	·536	

The theoretical quantity of water capable of being heated from 90°, and evaporated at, say 212°, with an infinite quantity of heating surface and a perfect fire, is somewhere about 13½ lbs. per pound of coal; whilst from the diagrams represented in Prof. Rankine's report of the *Thetis*' performance, 18 lbs. weight appears to be about the quantity of water per pound of coal. This calculation I have made from the diagrams published, and any party interested may repeat the calculations.

The calculation is made as follows:—The area of the large cylinder as shown in the diagram is 1380 square inches, or 9·583 square feet. The four revolutions of piston marked on the diagram, 49½, 52, 53, and 52 revolutions per minute, with a stroke of 2½ feet, or say 258·12 feet per minute, gives $258{\cdot}12 \times 9{\cdot}583 \times 60 = 146433$ cubic feet per hour. And if we take the average pressure shown in the four diagrams at the end of the piston stroke, supposing the barometer to be 14·5 lbs., we find the weight of that steam to be about 44 cubic feet per lb.; this number, therefore, divided by 44, gives the quantity of steam as 3300 lbs.

per hour; to this must be added one-twentieth for contents of ports and clearance, which makes 3465 lbs. of steam.

This clearly gives the weight of the steam per hour given out of the cylinders after the work is performed; to this, therefore, must be added the quantity of heat that must have disappeared during the performance of the work; this in the case of the *Thetis* is about $\frac{1}{5}$ of the entire heat; we must, therefore, add $\frac{1}{5}$, or, say, $3465+693=4158$ lbs. of water must have been raised from a temperature of about 100° and evaporated, or say 18 lbs. of water to the pound of coal said to be consumed. This result is about equal to 20 lbs. of water evaporated at 212° to the pound of coal consumed; a quantity quite absurd.

It would therefore appear, before a proper comparison could be established between the merits of the *Thetis*' boiler and that of any other boiler, a correct trial of the former would be necessary. In the meantime we have but to consider that the report of Prof. Rankine was based on one hour's consumption of, say 230 lbs. of coal, and compare that with a mass of boiler, water, and fire-brick weighing 20 tons, at a temperature of, say 300°, it is evident that the mass of heat in proportion to the coal consumed is so great that no conclusion should be made from such an experiment; also, that when the quantity of coal said to be consumed, viz., 230 lbs., is compared with area of fire-grate, say 40 square feet, it is evident that the result should not be depended upon, as no ordinary comparisons could be made of the condition of the fires before and after the experiment. In conclusion, let me ask of every one present to consider the trial trips of steamships and boilers in their true light, and before drawing any inference from such trials, make a perusal of results obtained from sea voyages. The evaporative power and economy of boilers is one of the most important subjects for this Society to consider. We need only to refer to the report drawn up by the Steam Shipping Committee of the British Association to show how mixed up the question of the relative efficiency of the boilers and engines is generally considered. Indeed, the American navy returns form the only reports showing the evaporative power of the boilers in this list, and the whole merit of a good evaporating boiler is often sacrificed to the character of the engines. With regard to the *Thetis*, I would recommend any mistake to be remedied as soon as possible, as there are many contracts of a most responsible nature formed in consequence of this report, that will lead to serious loss and disappointment to the steam shipping interest and to the engineering profession of this country.

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*A Sheet of Paper Four Miles Long.**

A sheet of tissue paper has been exhibiting at Colyton, Devonshire. It measures in length four miles, being 21,000 feet long, and is in breadth 6 feet 3 inches. The weight of it is but 196 pounds. It was manufactured in twelve hours.

*From the London Builder, No. 906.

A Course of Lectures, consisting of Illustrations of the Various Forces of Matter, i.e. *of such as are called the Physical or Inorganic Forces.** By M. FARADAY, D.C.L., F.R.S.

LECTURE VI. (Jan. 7, 1860.)—*The Correlation of the Physical Forces.*

We have frequently seen during the course of these lectures, that one of those powers or forces of matter of which I have written the names on that board, has produced results which are due to the action of some other force. Thus, you have seen the force of electricity acting in other ways than in attracting; you have also seen it combine matters together or disunite them by means of its action on the chemical force; and in this case, therefore, you have an instance in which these two powers are related. But we have other and deeper relations than these; we have not merely to see how it is that one power affects another—how the force of heat affects chemical affinity, and so forth, but we must try and comprehend what relation they bear to each other, and how these powers may be changed one into the other; and it will to-day require all my care, and your care too, to make this clear to your minds. I shall be obliged to confine myself to one or two instances, because to take in the whole extent of this mutual relation and conversion of forces would surpass the human intellect.

In the first place, then, here is a piece of fine zinc-foil, and if I cut it into narrow strips and apply the power of heat to it, admitting the contact of air at the same time, you will find that it burns; and then, seeing that it burns, you will be prepared to say that there is chemical action taking place. You see all that I have to do is to hold the piece of zinc at the side of the flame so as to let it get heated, and yet to allow the air which is flowing in to the flame from all sides to have access to it;—there is the piece of zinc burning just like a piece of wood, only brighter. A part of the zinc is going up into the air in the form of that white smoke, and part is falling down on to the table. This, then, is the action of chemical affinity exerted between the zinc and the oxygen of the air. I will show you what a curious kind of affinity this is by an experiment which is rather striking when seen for the first time. I have here some iron filings and gunpowder, and will mix them carefully together with as little rough handling as possible; now we will compare the combustibility, so to speak, of the two. I will pour some spirit of wine into a basin and set it on fire; and having our flame, I will drop this mixture of iron filings and gunpowder through it, so that both sets of particles will have an equal chance of burning. And now tell me which of them it is that burns. You see a plentiful combustion of the iron filings; but I want you to observe that though they have equal chances of burning, we shall find that by far the greater part of the gunpowder remains untouched; I have only to drain off this spirit of wine and let the powder which has gone through the flame dry, which it will do in a few minutes, and I will then test it with a lighted match. So ready is the iron to burn,

* From the Lond. Chemical News, No. 10.

that it takes, under certain circumstances, even less time to catch fire than gunpowder. [As soon as the gunpowder was dry Mr. Anderson handed it to the Lecturer, who applied a lighted match to it, when the sudden flash showed how large a proportion of gunpowder had escaped combustion when falling through the flame of alcohol]

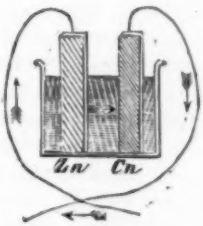
These are all cases of chemical affinity, and I show them to make you understand that we are about to enter upon the consideration of a strange kind of chemical affinity, and then to see how far we are enabled to convert this force of affinity into electricity or magnetism, or any other of the forces which we have discussed. Here is some zinc (I keep to the metal zinc as it is very useful for our purpose), and I can produce hydrogen gas by putting the zinc and sulphuric acid together as they are in that retort; there you see the mixture which gives us hydrogen—the zinc is pulling the water to pieces and setting free hydrogen gas. Now we have learned by experience that if a little mercury is spread over that zinc, it does not *take away* its power of decomposing the water, but *modifies* it most curiously. See how that mixture is now boiling, but when I add a little mercury to it the gas ceases to come off. We have now scarcely a bubble of hydrogen set free, so that the action is suspended for the time. We have not *destroyed* the power of chemical affinity, but modified it in a wonderful and beautiful manner. Here are some pieces of zinc covered with mercury exactly in the same way as the zinc in that retort is covered, and if I put this plate into sulphuric acid I get no gas, but this most extraordinary thing occurs, that if I introduce along with the zinc another metal which is *not* so combustible, then I reproduce all the action. I am now going to put to the amalgamated zinc in this retort some portions of copper wire (copper not being so combustible a metal as the zinc), and observe how I get hydrogen again, as in the first instance—there, the bubbles are coming over through the pneumatic trough, and ascending faster and faster in the jar; the zinc, so to speak, is acting by reason of its contact with the copper.

Every step we now take brings us to a knowledge of new phenomena. That hydrogen which you now see coming off so abundantly does not come from the zinc as it did before, *but from the copper.* Here is a jar containing a solution of copper. If I put a piece of this amalgamated zinc in it, and leave it there, it has hardly any action, and here is a plate of platinum which I will immerse in the same solution, and might leave it there for hours, days, months, or even years, and no action would take place. But now I put them both in together, and let them touch each other (Fig. 1). See what a coating of copper there is immediately thrown down on the platinum. Why is this? The platinum has no power of itself to reduce the metal from that fluid, but it has in some mysterious way received this power by its contact with the metal zinc. Here, then, you see a strange transfer of chemical force from one metal to another—the chemical force from the zinc is transferred, and made over to the platinum by the mere association of the two metals. I might take instead of the platinum, a piece of copper or silver, and it would have no action of its own on

this solution, but the moment the zinc was introduced and touched to the other metal, then the action would take place, and it would become covered with copper. Now, is not this most wonderful and beautiful to see? we still have the identical chemical force of the particles of zinc acting, and yet in some strange manner we have power to make that chemical force, or something it produces, travel from one place to another—for we do make the chemical force travel from the zinc to the platinum by this very curious experiment of using the two metals in the same fluid in contact with each other.

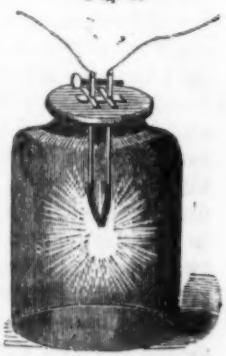
Fig. 1.

Fig. 2.



Let us now examine these phenomena a little more closely. Here is a drawing (Fig. 2) in which I have represented a vessel containing the acid liquid and the slips of zinc and platinum or copper, and I have shown them touching each other *outside* by means of a wire coming from each of them (for it matters not whether they touch in the fluid or outside—by pieces of metal attached they still by that communication between them, have this power transferred from one to the other). Now, if instead of using only one vessel, as I have shown there, I take another, and another, and put in zinc and platinum, zinc and platinum, zinc and platinum, and connect the platinum of one vessel with the zinc of another, the platinum of this vessel with the zinc of that, and so on, we should only be using a series of these vessels instead of one. This we have done in that arrangement which you see behind me. I am using what we call a Grove's voltaic battery, in which one metal is zinc and the other platinum, and I have as many as forty pairs of these plates all exercising their force at once in sending the whole amount of chemical power there evolved through these wires under the floor and up to these two rods coming through the table. We need do no more than just bring these two ends in contact, when the spark shows us what power is present; and what a strange thing it is to see that this force is brought away from the battery behind me, and carried along through these wires. I have here an apparatus (Fig. 3) which Sir Humphry Davy constructed many years ago, in order to see whether this power from the voltaic battery caused bodies to attract each other in the same manner as the ordinary electricity did. He made it in order to ex-

Fig. 3.

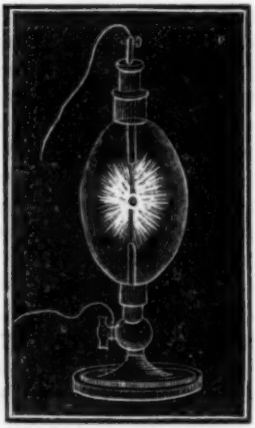


periment with his large voltaic battery, which was the most powerful then in existence. You see there are in this glass jar two leaves of gold, which I can cause to move to and fro by this rack work. I will connect each of these gold leaves with separate ends of this battery, and if I have a sufficient number of plates in the battery I shall be able to show you that there will be some attraction between those leaves even before they come in contact; if I bring them sufficiently near when they are in communication with the ends of the battery, they will be drawn gently together, and you will know when this takes place, because the power will cause the gold leaves to burn away, which they could only do when they touched each other. Now I am going to cause these two leaves of gold to approach gradually, and I have no doubt that some of you will see that they approach before they burn, and those who are too far off to see them approach will see by their burning that they have come together. Now they are attracting each other, long before the connexion is complete, and there they go! burnt up in that brilliant flash, so strong is the force. You thus see, from the attractive force at the two ends of this battery, that these are really and truly electrical phenomena.

Now let us consider what is this spark. I take these two ends and bring them together, and there I get this glorious spark like the sunlight in the heavens above us. What is this? It is the same thing which you saw when I discharged the large electrical machine, when you saw one single bright flash; it is the same thing, only *continued*, because here we have a more effective arrangement. Instead of having a machine which we are obliged to turn for a long time together, we have here a *chemical* power which sends forth the spark—and it is wonderful and beautiful to see how this spark is carried about through these wires. I want you to perceive, if possible, that this very spark and the heat it produces (for there is heat), is neither more nor less than the chemical force of the zinc—its *very* force carried along wires and conveyed to this place. I am about to take a portion of the zinc and burn it in oxygen gas for the sake of showing you the kind of light produced by the actual combustion in oxygen gas of some of this metal. [A tassel of zinc-foil was ignited at a spirit lamp and introduced into a jar of oxygen, when it burnt with a brilliant light.] That shows you what the affinity is when we come to consider it in its energy and power. And the zinc is being burned in the battery behind me at a much more rapid rate than you see in that jar, because the zinc is there dissolving and *burning*, and produces here this great electric light. That very same power which in that jar you saw evolved from the actual combustion of the zinc in oxygen is carried along these wires and made evident here, and you may if you please consider that the zinc is burning in those cells, and that *this* is the light of that burning [bringing the two poles in contact and showing the electric light]; and we might so arrange our apparatus as to show that the amounts of power evolved in either case are identical. Having thus obtained power over the chemical force, how wonderfully we are able to convey it from place to place; when we use gunpowder for explosive purposes, we can send

into the mine chemical affinity by means of this electricity; not having provided fire beforehand, we can send it in at the moment we require it. Now here (Fig. 4) is a vessel containing two charcoal points, and I bring it forward as an illustration of the wonderful power of conveying this force from place to place. I have merely to connect these by means of wires to the opposite ends of the battery, and bring the points in contact. See! what an exhibition of force we have. We have exhausted the air so that the charcoal cannot burn, and therefore the light you see is really the burning of the zinc in the cells behind me —there is no disappearance of the carbon, although we have that glorious electric light; and the moment I cut off the connexion it stops. Here is a better instance to enable some of you to see the certainty with which we can convey this force where, under ordinary circumstances, chemical affinity would not act. We may absolutely take these two charcoal poles down under water, and get our electric light there;—there they are in the water, and you observe when I bring them into connexion we have the same light as we had in that glass vessel.

Fig. 4.



Now, besides this production of light we have all the other effects and powers of burning zinc. I have a few wires here which are not combustible, and I am going to take one of them, a small platinum wire, and suspend it between these two rods which are connected with the battery, and when contact is made at the battery see what heat we get (Fig. 5). Is not that beautiful?—it is a complete bridge of power. There is metallic connexion all the way round in this arrangement, and where I have inserted the platinum, which offers some resistance to the passage of the force, you see what an amount of heat is evolved,—this is the heat which the zinc would give if burnt in oxygen, but as it is being burnt in the voltaic battery it is giving it out at this spot. I will now shorten this wire for the sake of showing you that the shorter the obstructing wire is, the more and more intense is the heat, until at last our platinum is fused and falls down, breaking off the circuit.

Fig. 5.

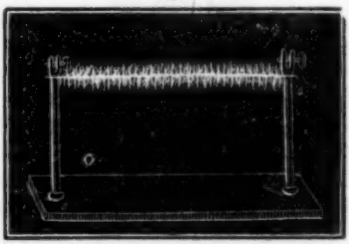
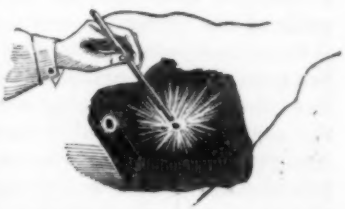


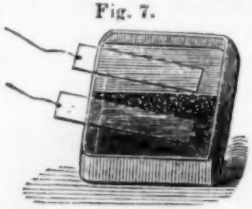
Fig. 6.



Here is another instance. I will take a piece of the metal silver and place it on charcoal connected with one end of the battery, and lower the other charcoal pole on to it—

see how brilliantly it burns (Fig. 6). Here is a piece of iron on the charcoal, see what a combustion is going on; and we might go on in this way burning almost every thing we placed between the poles. Now, I want to show you that this power is still chemical affinity—that if we call the power which is evolved at this point *heat* or *electricity*, or any other name referring to its source, or the way in which it travels, we still shall find it to be chemical action. Here is a colored liquid which can show by its change of color the effects of chemical action; I will pour part of it into this glass, and you will find that these wires have a very strong action. I am not going to show you any effects of combustion or heat, but I will take these two platinum plates, and fasten one to the one pole and the other to the other end, and place them in this solution, and in a very short time you will see the blue color will be entirely destroyed. See, it is colorless now—I have merely brought the end of these wires into the solution of indigo, and the power of electricity has come through these wires and made itself evident by its chemical action. There is also another curious thing to be noticed now we are dealing with the chemistry of electricity, which is that the chemical power which destroys the color is only due to the action on one side. I will pour some more of this sulphindigotic acid into a flat dish, and will then make a porous dyke of sand separating the two portions of fluid into two parts (Fig. 7), and now we shall be able to see whether there is any difference in the two ends of the battery, and which it is that possesses this peculiar action. You see it is the one on my right hand which has the power of destroying the blue, for the portion on that side is thoroughly bleached, while nothing has apparently occurred on the other side. I say *apparently*, for you must not imagine, that because you cannot perceive any action none has taken place.

Fig. 7.



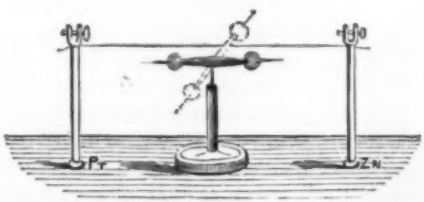
Here we have another instance of chemical action. I take these platinum plates again and immerse them in this solution of copper from which we formerly precipitated some of the metal, when the platinum and zinc were both put in it together. You see that these two platinum plates have no chemical action of any kind, they might remain in the solution as long as I liked, without having any power of themselves to reduce the copper; but the moment I bring the two poles of the battery in contact with them, the chemical action which is there transformed into electricity and carried along the wires, again becomes chemical action at the two platinum poles, and now we shall have the power appearing on the left hand side, and throwing down the copper in the metallic state on the platinum plate; and in this way I might give you many instances of the extraordinary way in which this chemical action or electricity may be carried about. That strange nugget of gold, of which there is a model in the other room, and which has an interest of its own in the natural history of gold, and which came from Ballarat, and was worth £8000 or £9000 when it was melted

down last November, was brought together in the bowels of the earth, perhaps ages and ages ago, by some such power as this. And there is also another beautiful result dependent upon chemical affinity in that fine lead-tree, the lead growing and growing by virtue of this power. The lead and the zinc are combined together in a little voltaic arrangement, in a manner far more important than the powerful one you see here, because in nature these minute actions are going on for ever, and are of great and wonderful importance in the precipitation of metals and formation of mineral veins, and so forth. These actions are not for a limited time, like my battery here, but they act for ever in small degrees, accumulating more and more of the results.

I have here given you all the illustrations that time will permit me to show you of chemical affinity producing electricity, and electricity again becoming chemical affinity. Let that suffice for the present; and let us now go a little deeper into the subject of this chemical force, or this electricity—which shall I name first?—the one producing the other in a variety of ways. These forces are also wonderful in their power of producing another of the forces we have been considering, namely, that of magnetism, and you know that it is only of late years, and long since I was born, that the discovery of the relations of these two forces of electricity and chemical affinity to produce magnetism have become known. Philosophers had been suspecting this affinity for a long time, and had long had great hopes of success—for in the pursuit of science we first start with hopes and expectations; these we realize and establish never again to be lost, and upon them we found new expectations of further discoveries, and so go on pursuing, realizing, establishing, and founding new hopes again and again.

Now observe this: here is a piece of wire which I am about to make into a bridge of force, that is to say, a communicator between the two ends of the battery. It is copper wire only, and is therefore not magnetic of itself. We will examine this wire with our magnetic needle

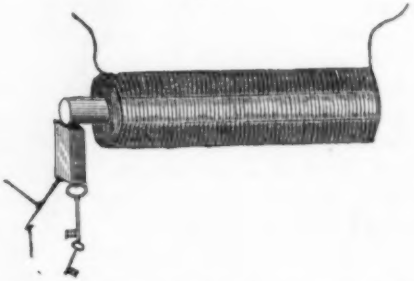
Fig. 8.



(Fig. 8), and though connected with one extreme end of the battery, you see that before the circuit is completed it has no power over the magnet. But observe it when I make contact; watch the needle, see how it is swung round, and notice how indifferent it becomes if I break contact again; so you see we have this wire evidently affecting the magnetic needle under these circumstances. Let me show you that a little more strongly. I have here a quantity of wire which has been wound into a spiral, and this will affect the magnetic needle in a very curious manner, because, owing to its shape, it will act very like a real

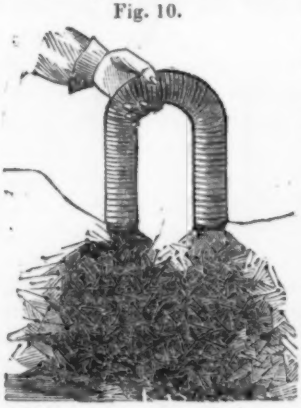
magnet. The copper spiral has no power over that magnetic needle at present, but if I cause the electric current to circulate through it, by bringing the two ends of the battery in contact with the ends of the wire which forms the spiral, what will happen? Why one end of the needle is most powerfully drawn to it; and if I take the other end of the needle it is repelled; so you see I have produced exactly the same phenomena as I had with the bar magnet,—one end attracting and the other repelling. Is not this then curious to see that we can construct a magnet of copper? Furthermore, if I take an iron bar, and put it inside the coil, so long as there is no electric current circulating round, it has no attraction,—as you will observe if I bring a little iron filings or nails near the iron. But now if I make contact with the battery they are attracted at once. It becomes at once a

Fig. 9.



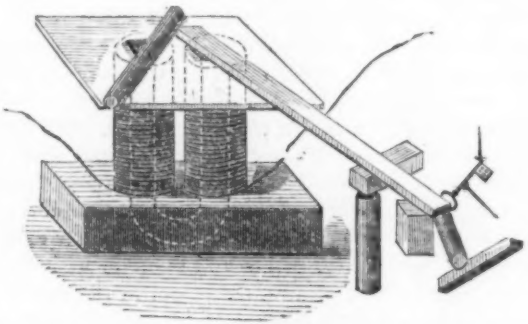
powerful magnet, so much so that I should not wonder if these magnetic needles on different parts of the table pointed to it. And I will show you by another experiment what an attraction it has. This piece and that piece of iron, and many other pieces are now strongly attracted (Fig. 9), but as soon as I break contact the power is all gone and they fall. What then can be a better or a stronger proof than this of the relation of the powers of magnetism and electricity? Again, here is a little piece of iron which is not yet magnetized. It will not at present take up any one of these nails; but I will take a piece of wire and coil it round the iron (the wire being covered with cotton in every part so that it does not touch the iron), so that the current must go round in this spiral coil; I am, in fact, preparing an *electro-magnet* (we are obliged to use such terms to express our meaning, because it is a magnet made by electricity, —because we produce by the force of electricity a magnet of far greater power than a permanent steel one). It is now completed, and I will repeat the experiment which you saw the other day, of building up a bridge of iron nails; the contact is now made and the current is going through; it is now a powerful mag-

Fig. 10.



net; here are the iron nails which we had the other day, and now I have brought this magnet near them they are clinging so hard that I can scarcely move them with my hand (Fig. 10). But when the contact is broken, see how they fall. What can show you better than such an experiment as this, the magnetic attraction with which we have endowed these portions of iron? Here again is a fine illustration of this strong power of magnetism. It is a magnet of the same sort as the one you have just seen. I am about to make a current of electricity pass through the wires which are round this iron for the purpose of showing you what powerful effects we get. Here are the poles of the magnet; and let us place on one of them this long bar of iron. You see as soon as contact is made how it rises in position (Fig. 11);

Fig. 11.



and if I take such a piece as this cylinder, and place it on, wo be to me if I get my finger between; I can roll it over, but if I try to pull it off, I might lift up the whole magnet, but I have no power to overcome the magnetic power which is here evident. I might give you an infinity of illustrations of this high magnetic power. There is that long bar of iron held out, and I have no doubt if I were to examine the other end I should find that it was a magnet. See what power it must have to support not only these nails but all these lumps of iron hanging on to the end. What then can surpass these evidences of the change of chemical force into electricity, and electricity into magnetism? I might show you many other experiments whereby I could obtain electricity and chemical action, heat and light from a magnet, but what more need I show you to prove the universal correlation of the physical forces of matter, and their mutual conversion one into another?

And now let us give place as juveniles to the respect we owe to our elders; and for a time let me address myself to those of our seniors who have honored me with their presence during these lectures. I wish to claim this moment for the purpose of tendering our thanks to them, and my thanks to you all for the way in which you have borne the inconvenience that I at first subjected you to. I hope that the insight which you have here gained into some of the laws by which the universe is governed, may be the occasion of some amongst you turning

your attention to these subjects; for what study is there more fitted to the mind of man than that of the physical sciences? And what is there more capable of giving him an insight into the actions of those laws, a knowledge of which gives interest to the most trifling phenomenon of nature, and makes the observing student find

> "——tongues in trees, books in the running brooks,
> Sermons in stones, and good in every thing."

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*Patent Steel Plates.** By DAVID LIVINGSTONE.

River Zambesi, East Africa, 12th January, 1860.

SIR:—The insertion of the following note in the *Journal of the Society of Arts* may prove of public service in preventing any other expedition trusting to a vessel built of the "patent steel plates," which have caused us so much toil, loss of time, and annoyance.

It is probable that there are purposes to which these patent steel plates might be applied with great advantage, but eighteen months experience in a steam punt constructed of this material, has proved that the substance cannot be trusted in tropical waters. Whatever may be the process by which the plates are converted into steel, a very remarkable decomposition soon takes place when exposed to the heat and moisture of this climate, and a considerable portion of the plate becomes what possibly is the black oxide of iron. In our case, the whole vessel was painted thoroughly, inside and outside, with Peacock's patent paint while on the deck of another vessel in the voyage out. But this proved no protection, for a process of decomposition began on both surfaces, altogether different from the common rust of iron. Scales of a jet black color were formed, and when detached the plates were found to be as smooth and black as if they had left the rollers but an hour before. The scales are black in their substance, too, and strongly magnetic. The paint, firmly adherent on the outer surface, showed that it had failed to prevent the process, and curiously enough, the rivets, which are probably of common steel, neither rusted nor decomposed. For a considerable time the process of scaling off and leaving a smooth, black, and even shining surface, made us believe that the plates were suffering no harm by exposure to the weather. Friction had no effect in wearing them. But the decomposition was going on at the same rate inside; blisters, also, were formed, and at the bottom of each there was a minute hole right through, and at the end of twelve months the removal of the internal surface scale left us with plates as thin as wafers, and so full of small holes our wretched craft might have been converted into a coffee strainer for the entire Society of Arts. The plates were only one-sixteenth of an inch in thickness at the beginning, and the internal scales are one-thirty-second of an inch. The framework being of the flimsiest contract style, any attempt at mending involving hammering or wedging would have been putting a new piece into an old garment, so we had to resort to puddling her with stiff clay. This served for a while, but the holes becoming too large, we were obliged to run down to the sea, and with the assistance of the tides,

* From the Journal of the Society of Arts, No. 400.

get her out of the water. By digging the sand from beneath, we reached the worst places, and the engineers, Messrs. Rae and Hill, assisted by men from H. M. S. *Lynx*, put planks outside and inside, with plies of canvass and white lead, sandwich fashion, and guaranteed her to float any time between three days and six weeks. New leaks, however, forced us to beach before the first period mentioned, and though rather annoyed at being kept tinkering, instead of doing good service to the cause of African civilization, we must, as we have often done with disagreeables before, "put up with it."

No advantage whatever has been gained by the employment of these steel plates. The contractor intended that by their use the vessel should draw thirteen inches only, but when we tried her fairly out here in salt water, without fuel, gear, crew, or water in the boiler, she drew twenty-three inches, and her paddle floats are, of course, ten inches too deep. It was promised that she could carry from ten to twelve tons, but four tons bring her down to 2 ft. 7 ins. and within a few inches of the paddle wheel shaft, while six tons would sink her altogether.

Nor have we gained the least in speed, for, instead of "ten knots, at least," promised, we have to be content with a top speed of $3\frac{1}{4}$. This may in part be owing to the peculiar form adopted—an imitation of the Niger canoes, *i. e.*, long, narrow, and turned up at the ends. The negro reasons for this shape are sensible enough. They cannot make them broader than the trees, and make up in length what they cannot have in breadth, and they are turned up at the ends to avoid the shock which would be felt in coming to a bank, were they not made to slide up. These reasons are not so very recondite as to induce us to forsake the wave line of Mr. Scott Russell surely. Here we often see canoes made out of crooked trees, and as they are simply hollowed out, the canoe retains the bends of the stock. Some future contractor, if using other people's money, may infer that these crooked canoes are exactly suited for turning round corners, instead of inferring that the owners had no straight trees near the river.

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*On Foot Valves in Condensers and Air Pumps.**

The subject of foot valves in air pumps has, by engineers, been too much overlooked. It is of the greatest importance in marine engines, particularly in propeller engines, where the machinery is applied direct to the propeller shaft. Captain Carlsund, in Motala, I believe was the first engineer who paid attention to the proper arrangement in air pumps and foot valves; he applies his machinery with the air pump direct to the propeller shaft, making 100 to 140 revolutions per minute, and is found to work exceedingly well, while in America and England they have been obliged to gear the air pump down to a slower motion, or when attempting to apply it direct to direct action machinery, it has sometimes ended in a total destruction of the whole; the true cause of the blunder has been concealed and made over and over again.

The disproportion of foot valves has caused the loss of millions of

* From the Lond. Artizan, Oct., 1860.

dollars in America; for instance, the first engines on the frigate *San Jacinto*, U. S. N., broke down from the disarrangements of the air pumps. The *La Fayette's* engines, which I believe had the worst air pumps ever constructed for the purpose, broke down from the same cause; also, the *City of Petersburg*, and others, all American first-class steamers.

When the air pump is working, the water is forced through the foot valve by the pressure or the deficiency of vacuum in the condenser. Every pound of pressure per square inch balances a column of water of about 27 inches high; for instance, if the vacuum in the condenser is 24 inches of mercury, which is termed 12 pounds per square inch, and the atmospheric pressure being 14·75, then $14{\cdot}75 - 12 = 2{\cdot}75$ lbs., which will be the pressure per square inch in the condenser, and $2{\cdot}75 \times 27 = 74{\cdot}25$ inches, or 6·2 feet, the head, which presses the water through the foot valve into the air pump. According to the relative position of the condenser and air pump, there may be an additional head, as when the water level in the condenser is above the air pump piston.

I will here endeavor to give some formulæ, by which to determine the area of foot valves, and size of air pumps, which will be found to be of the greatest importance for propeller engines.

D = diameter of steam cylinder in inches.
S = stroke of piston in inches, double acting.
d = diameter of air pump in inches.
s = stroke of air pump piston in inches.
a = area of foot valves in square inches.
n = number of double strokes of the air pump piston per minute, when the air pump is applied direct to the engines.
m = co-efficient for friction and resistance to the water in passing through the foot valve, estimated to 0·6 to 0·7.
p = pressure in the condenser, or deficiency of vacuum in pounds per square inch.
T = temperature of the exhaust steam, Fahrenheit's scale.
k = specific volume of the exhaust compared with water.

Assuming the temperature of the condensing water 100°, and the injection water 50° Fahrenheit's scale, we shall have the following formulæ:

Single acting air pumps.

$$d = 0{\cdot}326\ \mathrm{D}\sqrt{\frac{\mathrm{S}\ (890 + \mathrm{T})}{k\ s}},$$

$$s = 0{\cdot}106\ \mathrm{D}^2\ \frac{\mathrm{S}\ (890 + \mathrm{T})}{k\ d^2},$$

Double acting air pumps.

$$d = 0{\cdot}231\ \mathrm{D}\sqrt{\frac{\mathrm{S}\ (890 + \mathrm{T})}{k\ s}},$$

$$s = 0{\cdot}053\ \mathrm{D}^2\ \frac{\mathrm{S}\ (890 + \mathrm{T})}{k\ d^2},$$

$$a = \frac{\mathrm{D}^2\ \mathrm{S}\ n\ (890 + \mathrm{T})}{23{,}000\ m\ k\ \sqrt{p}}$$ area of foot valve.

By the last formula, it appears, the proper area of the foot valve is

independent of the capacity of the air pump,—such is actually the case; if the foot valve is made too small the air cannot pump water enough for a good vacuum, however large it may be. It is most frequently the case in propeller engines that the air pump is too large and the foot valve too small.

Example.—A single acting air pump is to be constructed for an engine of

$D = 75{\cdot}75$ inches, the diameter of cylinder.
$S = 36$ inches, the stroke of piston.

Steam pressure to be 20 lbs. per square inch, expanded $\frac{1}{2}$; vacuum in the condenser to be 12·75 lbs., or $p = 2$; stroke of the air pump piston to be $s = 18$ inches. Required, the diameter of the air pump d, and area of the foot valve a?

Steam pressure, $20 + 15 = 35$ lbs.; expanded one-half $= 17{\cdot}5$ lbs., the pressure of the exhaust steam; temperature $T = 221°$, and $k = 1440$ the specific volume. The diameter of the air pump will be

$$d = 0{\cdot}326 \times 75{\cdot}75 \sqrt{\frac{36\,(890 + 221)}{1440 \times 18}} = 30{\cdot}64 \text{ inches.}$$

The air pump making $n = 45$ double strokes per minute, area of the foot valve will be

$$a = \frac{75{\cdot}75^2 \times 36 \times 45\,(890 + 221)}{23{,}000 \times 1440 \times 0{\cdot}64 \times \sqrt{2}} = 344 \text{ square inches.}$$

The dimensions in this example are similar to that of the engines in the line-of-battle ship *Rattvisan*, except the air pumps, are there 42 inches diameter, and area of the foot valve is only 273 square inches, while this example gives only 30·64 diameter, and 344 square inches of foot valve.

This, I believe, is an error in all the upright trunk propeller engines.

Referring to the *Artizan* for November, 1856, it will be found that the United States steam frigate *Merrimac* suffered the breaking down of her foot valves on her passage from America to England. The *Artizan* states that the original foot valves were only 176 square ins., that new ones were replaced of 230 square inches, while the frigate laid at Southampton, and that about one pound of vacuum was gained with the increased foot valve. Dimensions of the engines of the *Merrimac* are, diameter of cylinders 72 inches, stroke of piston 3 feet, diameter of air pumps 22 inches, stroke of air pump 3 feet double acting.

When, by this calculation and formulæ, the area of the foot valve becomes nearly the same size, or greater than the area of the air pump piston, the latter must be made double acting, and half the calculated area of the foot valve to be applied at each end of the air pump. In very high velocity the area of the foot valve may become greater than the area of the double acting air pump; in such cases it is necessary to make plungers, so that the section area of the space in which the plunger moves is greater than the area of the foot valve, and the operation will be rendered efficient.

*On Etching.**

Ornamentation on metals, glass, and porcelain, has come into considerable use; and, believing as we do, that such work would not only be pleasant to amateurs, but might also be useful to others, we think that a few brief and practical notes on the subject may not be out of place.

First, as regards copper plates—which in many respects have an advantage over steel for the use of amateurs,—procure a thin plate, properly polished on the surface, at any of the regularly established copper-smiths. These can be had of the size of several feet down to a few inches. The surface of the plate being bright and free from tarnish, remove all grease with great care by washing with spirit of turpentine and then rubbing with very fine whitening and wash-leather. Care must be taken not to scratch the plate.

Having got rid of all grease, fix a hand-vice to one corner or some other convenient part of the plate; it is then ready for the reception of the etching-ground—a preparation chiefly composed of asphaltum, pitch, and virgin wax; there is, however, a great art in making this sufficiently plastic, so as to admit of its being properly spread upon the plate when heated. It is better for ordinary purposes to purchase it at the copper-smith's or tool-shop, where a supply can be had for about one shilling. A dabber, for the purpose of laying the ground on the plate, is also necessary. This is of a mushroom shape, and composed outwardly of very fine silk or kid leather, free from grease; the inside is padded with wool. This can be readily made by any person who has seen one of them. In order to prevent any grit or impurity which may chance to be in the etching-ground, it is better to tie it in silk. For the purpose of heating the plate, a hot iron, or a spirit lamp, placed below an iron frame on which the plate may rest, or other contrivance may be used. Care is to be taken to make as little dust as possible. The metal must not be allowed to get too hot, for that would burn the etching-ground, and prevent it from sufficiently resisting the acid. The plate being of a proper heat, by drawing the etching-ground over the face, a small quantity will be lodged upon it. This in the first instance is uneven; but may be spread in a flat, thin, even manner. Every part must be covered by the ground, or else the acid would leave such places as are bare liable to be corroded into holes. The ground, when this is spread on the surface, is of a light brown color, so delicate that it is difficult to see any pencil outline which might be transferred, or properly to see the scratches made by the etching-needle. In order to darken this, it is necessary, while the plate and etching-ground are still warm, to smoke it by the flame of a wax taper or candle. The flame must be kept moving about, and not allowed to touch the plate so closely as to burn the ground.

These operations, although simple, require some little practice and experience; and it is, perhaps, a good plan either to take a lesson or two in ground-laying, and the other parts of this process, from an en-

* From the Lond. Builder, No. 918.

graver, or else to get one of this profession to lay the ground and bite in the plate when etched.

The ground having been made ready and the plate cold, an outline of the subject, prepared on ordinary or tracing paper, should be damped and transferred by means of pressure. The best way to manage this is to take it to a copper-plate printer, who will do it effectually for a few pence; for those living in the country where such convenience cannot properly be had, this transfer can be made by one of the ordinary letter copying machines, or by going very delicately over the back of the outlines with a pencil or other instrument which is not too sharp.

This having been done by means of an etching-point, which can be had at the tool-makers, the design can be readily scratched upon the plate. Attention is needed to mark the lines quite through the ground. The hand should also be prevented from coming in contact with the ground, and all unnecessary scratches be carefully avoided. This may, to a considerable extent, be done, by forming a bridge of a flat ruler, supported by pieces of card-board or folded paper.

Wherever the etching-ground has been passed through by the etching-needle, that part is liable to be eaten into a line by the application of acid; on no other portion however, if properly done, should the acid work.

It being necessary to cover the etching with an even depth of diluted acid (from a quarter to half an inch), in order to produce equality in the *biting*, it is needed to form a wall of wax round the margin of the work. The best material for this is bees-wax with a small part of Burgundy-pitch added, and then the mixture boiled until the whole is well mixed. This, when needed for use, should be put into warm water, and then it can be readily raised round the plate and pressed down by the fingers, and after that more firmly by the handle of the etching-point, so that a sort of tank is formed, which will contain the acid as long as it may be necessary.

With the greatest care scratches may be made, or it may be necessary to erase parts, or the wax wall may not be sufficiently tight. In order to remedy this, turpentine-varnish, or the ordinary "Brunswick black" used for stoves, may be employed, thinned to a proper extent by turpentine, and applied with a black-lead pencil.

For the purpose of "biting in" the plate, as the engravers call it, nitrous acid of the purest description should be mixed—one part of acid and three parts water—which should be stirred up with a feather or pencil; soon the lines will be covered with minute globules; and, in proportion to the time the acid is allowed to remain, the etched lines will become thicker and deeper.

As a matter of course, in order to produce a delicate and refined effect a variety of thicknesses of line is desirable; and, although much can be done by the pressure of the point, by hatching, doubling lines, &c., it is in most cases necessary to allow the acid different times of action; for instance, it will be desirable to keep distant mountains and landscape thin, and to bring out the foreground by bold and deep lines. In order to manage this, the acid must be poured off into a vessel for further use, and then the plate must be well washed with clear water,

and afterwards dried with a bellows or other means; then such parts of the etching as are of sufficient depth should be covered with the varnish in the same manner as the blemishes to which we have referred. This operation may be performed any number of times, each time washing and drying the plate; this must be also done when the biting is completed; and, then, by gently heating the back of the plate, the wall may be drawn off, and by means of a little spirit of turpentine and oil, the surface of the plate may be cleared of the etching-ground. There are other operations, such as re-biting, re-etching (by touching with the graver), and by working with a point without the use of acid, &c., &c.; these, however, would require much space to describe, and this we will not just now do, as it is more particularly our object in mentioning the above to make operations which might be useful in many manufactures more readily understood.

In the same manner, but with the use of different acids, and on any scale, etching may be applied to steel, iron, brass, glass, and, lately, we are told, to porcelain. For steel, nitric acid very largely diluted with pyroligneous acid until it does not taste much stronger than vinegar, is best. On brass we have seen diaper and other ornaments produced with great clearness and rapidity in the following manner. On large works, such as monumental brasses, experience has shown that in the biting, either by nitric or nitrous acid, before a great depth is got the biting of the lines is stopped by the formation of a black oxide, which it requires a very strong preparation of nitrous and sulphuric acid to remove and keep in solution; and this after a time proves too strong, and tears up the ordinary etching-ground; it has, however, been found that turpentine-varnish, if allowed for a few days to harden, has a great resistance; and by the use of this when diapers, &c., are outlined, the raised parts may be painted with the varnish; and, when hard, the acid applied; and it is astonishing what good effect may be produced by these means. Large surfaces for the relief of foliage, figures, letters, &c., may by this means, be executed with rapidity, either for filling in with colored shellac or pigments.

The painting of these ornamental plates with varnish might be the means of affording employment to females, and probably the preparation of embossing, and otherwise ornamenting glass to be bitten by fluoric acid, might also be brought into far more extensive use than it is at present, and would also provide a certain amount of respectable labor for females.

AMERICAN PATENTS.

AMERICAN PATENTS ISSUED FROM SEPTEMBER 1, TO SEPTEMBER 30, 1860.

Amalgamator,	G. M. Norton,	San Francisco,	Cal.	18
Amalgamators,—Quartz	Wm. H. and I. Scoville,	Chicago,	Ill.	25
Annealing Apparatus,	Joseph Worcester,	Newport,	Ky.	25
Apple Parer, Corer, and Slicer,	J. J. Parker,	Marietta,	Ohio,	11
Aqueducts,	John Osborn,	Mt. Carmel,	Conn.	4
Augers,	J. M. Hathaway,	City of	N. Y.	4
Axes to Handles,—Fastening	W. H. Livingston,	"	"	25
Barometer,	E. F. Hamann,	Collikoon,	N. Y.	18
Barrel-head Machine,	C. B. Hutchinson,	Auburn,	"	11

Bathing Tubs,—India-rubber	Ramsay & Wilson,	Grafton,	Va.	4
Bed Bottom Spring,	H. R. Crampton,	Lockport,	N. Y.	18
Bedstead,	B. S. Pringle,	Barnesville,	Ga.	4
———,—Folding Case	Ethan Whitney,	Lynn,	Mass.	18
———,—Spring	D. R. Lightner,	Bucyrus,	Ohio,	4
Beehives,	John Jacobs,	Columbus,	"	25
Beer,—Factitious	Ferdinand Luedke,	City of	N. Y.	25
Bending Wood,	Spaulding & Pierce,	Westminster,	Mass.	11
Billiard Tables,—Cushions for	H. W. Collender,	City of	N. Y.	25
Blowers,	P. H. Roots,	Connersville,	Ind.	25
Boards,—Machine for Thinning	Sharon Case,	Lumpkin,	Ga.	4
Bolt,—Shutter	Augustus Reeve,	Alloways'town,	N. J.	18
Bombshells,	Wm. Rice,	Philadelphia,	Penna.	11
Bottles,—Forming Screws in	John Focer,	Glassborough,	N. J.	18
Boots and Shoes,	J. M. Allen,	Fredericktown,	Ohio,	18
———————,—Heel for	D. E. Somes,	Biddeford,	Me.	18
Boot and Shoe Soles,—Cutting	L. S. Graves,	Rochester,	N. Y.	18
Boxes,—Device for Joining	Wright Duryea,	City of	"	11
Brick Moulds,	Matthew Elder,	Lansing,	Mich.	11
Broom,	W. H. Towers,	City of	N. Y.	4
Buckwheat, &c.,—Cleaning	J. H. Reed	Penn Towns'p,	Penna.	4
Burglar Alarm,—Electro-mag.	Jacob Haller,	Ann Arbor,	Mich.	25
Candles,—Moulding	Antonio Meucci,	Richmond co.,	N. Y.	25
Cane Juice,—Sulphurous acid to	Thomas Byrne,	Baton Rouge,	La.	4
Carpet Lining,—Making	J. R. Harrington,	City of	N. Y.	11
Carriage Jack,	J. Card,	Cleveland,	Ohio,	25
Carriages,	Efner & Sperry,	Ann Arbor,	Mich.	4
———	Wicklin & Weaver,	Carlinville,	Ill.	4
———,—Extension,	J. A. Naylor,	Rahway,	N. J.	4
Cars from one track to another,	Wm. Wharton, Jr.,	Philadelphia,	Penna.	18
Cartridges,—Metallic	Ethan Allen,	Worcester,	Mass.	25
Cement,	P. A. Letourneur,	New Orleans,	La.	11
Chains,—Link for	G. W. N. Yost,	Yellow Springs,	Ohio,	11
Chair for Invalids,	Chas. Messenger,	Warren,	"	25
—— Seat,	L. B. Batcheller,	Rochester,	N. Y.	11
Cheese,—Pressing	Wm. McAllister,	Gerry,	"	4
——— Vats,	Wm Ralph,	Holland Patent,	"	25
Clothes Frame,	S. T. Lamb,	N. Washington,	Ind.	18
———	Patrick Cody,	Hamilton,	N. Y.	25
——— Dryer,	H. E. Fickett,	Glenn's Falls,	"	4
———	O. P. Allen,	Rindge,	N. H.	11
Clock,—Calendar	T. T. Strode,	Mortonville,	Penna.	25
Coffee,—Cleaning, Drying, &c.	Wm. Newell,	Philadelphia,	Penna.	18
Compass Protractor,	F. H. West,	San Francisco,	Cal.	25
Condensation,—Apparatus for	Mihan & Lane,	Boston,	Mass.	18
Corn Planters,	W. G. Savage,	Clinton,	Ill.	25
———	John Underwood,	Cameron,	"	25
———	L. F. Straight,	Fairbury,	"	11
—— Shellers,	Michael Hauseman,	Huntingdon,	Ind.	4
——— and Cleaners,	J. C. Richards,	Lafayette,	"	25
Cotton Bales,—Iron Ties for	P. Davy,	Portsmouth,	Ohio,	25
———,—Metallic Bands	R. W. Fenwick,	Washington,	D. C.	25
——— Cleaners,	S. C. Ames,	Washington,	Ark.	11
———	Isaac Hayden,	Lawrence,	Mass.	11
———	Charles Smith,	Knoxville,	Texas,	11
——— Gins,	H. L. Emery,	Albany,	N. Y.	4
———,—Feeders for	S. Z. Hall,	Sequin,	Texas,	11
——— Scrapers,	J. C. Teague,	Center Hill,	Miss.	4
——— Seed,—Hulling	Joel Tiffany,	Syracuse,	N. Y.	18
——— Planters,	O. L. Gibson,	Fort Bend co.,	Texas,	11
Couplings,—Railroad Car	John McKinney,	Lansing,	Mich.	4
——— for City Railroads,	Collyear & Patterson,	Philadelphia,	Penna.	11

Cultivators,	T. E. C. Brinly,	Louisville,	Ky.	25
———	Gilbert & Weston,	Starkville,	Ga.	4
———	Wm. H. and L. Seymour,	Weymouth,	Ohio,	11
———	J. F. Wood,	Houma,	La.	25
———	G. W. N. Yost,	Yellow Springs,	Ohio,	4
———,—Cotton	W. W. Golsan,	Autaugaville,	Ala.	4
———	J. C. Sellers,	Woodville,	Miss.	25
Curtain Fixture,	J. F. Hall,	Bangor,	Me.	4
———	J. C. Whitwell,	City of	N. Y.	25
Dental Chairs,—Construction of	Justus Ask,	Lyons,	N. Y.	4
Dividers,—Spring	J. W. Strange,	Bangor,	Me.	11
Door Latch,	Jonathan Walton,	Brooklyn,	N. Y.	11
Doors and Gates,—Closing	Stephen Stewart,	Philadelphia,	Penna.	11
Draw-bridges,—Self-acting	Schneider & Montgomery,	Williamsport,	"	4
Egg-beater,	H. F. Drott,	Cumberland,	Md.	18
———	Nicholson & Earle,	Providence,	R. I.	25
Electro-magnets,	C. T. Chester,	City of	N. Y.	4
Electro-magnetic Apparatus,	Jerome Kidder,	"	"	18
Envelope,—Prepaid	J. B. Murray,	"	"	25
Excavating Machines,	M. B. True,	Newburyport,	Mass.	18
Faucets,	L. L. Alrich,	Carthage,	Mo.	25
———	Wm. Cleveland,	Orange,	N. J.	25
———	James Farnan,	Cleveland,	Ohio,	18
Fences,	Henry Burrows,	Georgetown,	D. C.	11
Fibrous Material,—Sheets of	Wm. Fuzzard,	Charlestown,	Mass.	18
Fire Arms,	C. F. Brown,	Warren,	R. I.	18
———,—Breech-loading	Ethan Allen,	Worcester,	Mass.	18
———,—Revolving	J. M. Cooper,	Pittsburgh,	Penna.	4
———	Daniel Moore,	Brooklyn,	N. Y.	18
Fire-places,	C. A. Littlefield,	Covington,	Ky.	11
Floodgates,—Self-acting	G. B. Markham,	Mead's Mills,	Mich.	4
Flour,—Preparation of	Thomas Byrne,	Baton Rouge,	La.	4
Furnaces,	Mellen Battel,	Albany,	N. Y.	18
———	W. D. Thomas,	Morristown,	Vt.	4
———,—Bagasse	Jones & Charpentier,	New Orleans,	La.	18
———,—Hot-air	A. H. Bartlett,	Spuyten Duyvil,	N. Y.	18
Gas from Wood,—Making	August Schmidt,	City of	"	4
Gas Tubes,—Flexible	T. J. Mayall,	Roxbury,	Mass.	4
Gearing,—Machine	R. J. Gatling,	Indianapolis,	Ind.	18
Glass Jars,—Moulds for	R. Hemingray,	Covington,	Ky.	18
—— Moulds,	G. W. Scollay,	St. Louis,	Mo.	18
Grading Instrument,	S. L. Donnell,	S. Carroll,	Tenn.	11
Grain Cleaning Machine,	J. B. Tunison,	Ovid,	N. Y.	18
———,—Cleaning and Polishing	Plant & Raith,	St. Louis,	Mo.	18
——— Elevators,	T. H. Green,	Fon du Lac,	Wis.	4
——— Separators,	Moses Bugher,	New Philada,	Ohio,	18
———	S. M. Wirts,	Hudson,	Mich.	11
———,—Separating & Scouring	D. S. Mackey,	Batavia,	N. Y.	18
———,—Sieves for Separating	H. W. Putney,	Lyons,	N. Y.	25
Grate Bars,	Daniel Lasher,	Brooklyn,	"	11
———	W. W. Marsh,	Alton,	Ill.	18
Griddles,	G. W. Pittock,	Union Mills,	N. Y.	11
Gun Carriage,	J. J. Walsh,	City of	"	25
Harness,—Snap Hook for	John North,	Middletown,	Conn.	18
Harrows,	M. W. House,	Cleveland,	Ohio,	4
———	Stewart Neill,	Chillicothe,	Ill.	4
Harvester Cutters,	B T. Roney,	Philadelphia,	Penna.	11
Harvesters,	H. H. Foye,	Ottawa,	Ill.	25
———	J. M. Long,	Hamilton,	Ohio,	4
———,—Rake and Reel for	McClintock Young, Jr.,	Frederick,	Md.	18

Harvesters,—Raking Appa's for	W. A. Wood,	Hoosick Falls,	N. Y.	11
———	C. P. Gronberg,	Aurora,	Ill.	11
Harvesting Machines,	Bernhard Mertz,	Burlington,	Iowa,	11
Hatchways,—Opening & Clos'g	E. C. Ford,	City of	N. Y.	25
Hats,—Ventilating	Arthur Maginnis,	Philadelphia,	Penna.	11
Hay Elevating Forks,	L. A. Beardsley,	S. Edmeston,	N. Y.	11
—— Rakes,	C. J. Fay,	Hammonton,	N. J.	25
—— and Straw Cutters,	J. D. Felthousen,	Mich. City,	Ind.	18
———	D. H. Whittemore,	Lynchburg,	Va.	4
Heating by Hot Water,	Hunter & Geissenhainer,	City of	N. Y.	18
Heating Buildings,—Appa's for	George Marlow,	Cincinnati,	Ohio,	11
Hemp Brakes,	R. J Gatling,	Indianapolis,	Ind.	4
———	Ives Scoville,	Chicago,	Ill.	25
Hops,—Preserving	J. C. Baldwin and others,	Waterville,	N. Y.	25
Horse Collars,—Hames for	Martin Drew,	St. Paul,	Minn.	18
Horse-powers,	Benjamin Bogue,	Trenton,	Iowa.	4
Horse Rakes,	Daniel Strock,	Chambersburg,	Penna.	11
Horses to Vehicles,—Attaching	Austin Avery,	S. Windham,	Conn.	18
Hose,—Waterproof	H. A. Alden,	Matteawan,	N. Y.	18
Hydrants,	Albert Fuller,	Cincinnati,	Ohio,	4
Jack Screws,	E. W. Cady,	Tomah,	Wis.	11
Journal Boxes,	P. S. Devlan,	Elizabethport,	N. J.	25
Lamps,	H. J. Batchelder,	Marlboro',	Mass.	18
———	George Neilson,	Boston,	"	18
——— or Torches,—Swinging	L. T. Pitkin,	Hartford,	Conn.	18
———,—Hanging Torch	C. H. Cooper,	City of	N. Y.	18
———,—Moulds for Glass	Joshua Jenkins,	Boston,	Mass.	18
Lifting Jack,	George Benjamin,	Avoca,	N. Y.	18
Lightning Rods,	David Wooster,	Seymour,	Conn.	4
Locks,	J. L. Hall,	Cincinnati,	Ohio,	25
———	C. F. Johnson and others,	Owego,	N. Y.	11
———	George Rosner,	Rochester,	"	18
———	E. P. Whitney,	Westfield,	"	4
Lock for Burglar-proof Pockets,	Wm. J. Scott,	Albany,	"	25
——,—Portable Door	E. G. F. Arndt,	Rondout,	"	18
Locomotive Engines,	A. J. Graham,	Portland,	Oregon,	4
———,—Dischar.	John Greacen, Jr.,	City of	N. Y.	4
Looms,—Power,	Furbush & Crompton,	Worcester,	Mass.	4
Magneto-electric Apparatus,	H. N. Baker,	Binghampton,	N. Y.	4
Malt Kilns,—Floors for	Henry Franz,	Philadelphia,	Penna.	25
Manure Spreader,—Roller and	John Lyker,	Argosville,	N. Y.	25
Meat Cutter,	J. G. Perry,	S. Kingston,	R. I.	18
Medicinal Extracts,—Prepar. of	A. J. Despinoy,	Lille,	France,	18
Milk-straining Pails,	H. Buckins,	Canton,	Ohio,	18
Mills,—Fanning	B. F. Roe,	Nebraska City,	Nebr.	11
——,—Feeding Grain to	M. H. Ferguson,	Sunfish,	Ohio,	11
Mill-dams,—Waste Gates for	Sidney Hudson,	Milford,	Mich.	4
Millstones,—Balancing	D. Fellenbaum,	Lancaster,	Penna.	4
———,—Dressing	C. D. Brewer,	Lewisburg,	"	4
———,—Hanging	Z. McDaniel,	Bowling Green,	Ky.	11
Miter Box,	H. B. Nash,	Sandy Hill.	N. Y.	11
Mop Wringer,	C. S. Schmidt,	City of	"	25
Mortising Machines,	H. C. Smith,	Clarksville,	Ohio,	4
Motion,—Stopping & Changing	F. A. Pratt,	Hartford,	Conn.	4
Mowing Machines,	Henry Marcellus,	Amsterdam,	N. Y.	4
———,—Hand	J. M. Spencer,	Enfield,	Me.	4
Ore Washer,	B. O'Bryan,	Lancaster,	Penna.	18
Paddle Wheel,—Stern	D. K. Peoples,	Philadelphia,	Penna.	18
Paper,—Trimming	Julius Koch,	S. Adams,	Mass.	4
Parasols,	Davis & Frost,	Watertown,	Conn.	25

Patterns,—Marking Waving	Albert Moffet,	Bristol,	Ohio,	4
Piles by Atmos. Pressure,—Driv.	W. S. Smith,	Trenton,	N. J.	4
Pipe,—Casting	Alfred Brady,	City of	N. Y.	18
Pipes,—Moulding Metal	Homer Parmalee,	Philadelphia,	Penna.	4
——,—Tapping Water	Jacob Drake,	City of	N. Y.	18
Planes,—Moulding	Chas. Fleming,	Ypsilanti,	Mich.	11
Planing Machine,	H. D. Stover,	City of	N. Y.	4
Planing Mouldings,	Wm. Rankin,	Providence,	Va.	11
Ploughs,	T. E. C Brinly,	Louisville,	Ky.	4
———	G. W. Cunningham,	Paris,	Mo.	25
———	H. J. Fraser,	Kansas City,	"	25
———	Walter Warren,	Penn Yan,	N. Y.	25
———	W. T. Zollickoffer,	Shelbyville,	Tenn.	25
———,—Mole	W. B. Atkinson,	Plymouth,	Ill.	18
———————	H. Bagley,	Tipton,	Iowa,	18
———————,—Capstans for	A. Little and others,	Decatur,	Ill.	11
Post Holes,—Earth Borers for	A. S. Ballard,	Mt. Pleasant,	Ind.	25
Potato Planters,	G. W. and J. J. Kersey,	Beartown,	Penna.	25
Presses,—Anti-friction	A. H. Emery,	City of	N. Y.	11
———,—Drop	M. and C. Peck,	New Haven,	Conn.	4
———,—Cotton	P. G. Gardiner,	City of	N. Y.	4
———————	W. T. Opie,	Scarboro,	Ga.	4
———————	Maximilian Wappich,	Sacramento,	Cal.	4
Projectiles,	J. W. Cochran,	City of	N. Y.	25
Propulsion,—Marine	L. B. Flanders,	Cleveland,	Ohio,	18
Propeller,—Marine	A. E. Harding,	Middletown,	"	11
Pumps,	Henry Pease,	Brockport,	N. Y.	11
———	G. C. Selfridge,	N. Greenfield,	"	4
Railroads,	B. F. Lee,	City of	N. Y.	11
Railroad Cars,—City	Joseph Harris, Jr.,	Roxbury,	Mass.	4
—— —— Frog,	J. M. Robb,	Charleston,	S. C.	25
———————,—Substitute for	Black & Ford,	Erie,	Penna.	25
——— Joints,	L. B. Tyng,	Lowell,	Mass.	11
——— Switch,	G. E. Beach,	Jersey City,	N. J.	25
Railroads,—Safety Guards for	Thomas Stewart,	Pittsburgh,	Penna.	11
Rakes,—Horse	J. C. Stoddard,	Worcester,	Mass.	11
Ranges and Stoves,	J. G. Treadwell,	Albany,	N. Y.	11
Reaping Machines,	W. S. Stetson,	Baltimore,	Md.	25
Reed Instrument,—Steam	G. G. Ray,	Boston,	Mass.	4
Refrigerator,	Kirby Spencer,	Minneapolis,	Ind.	25
Rice,—Cleaning	Silas Dodson,	San Francisco,	Cal.	25
——,—Polishing	Daniel Lombard,	Boston,	Mass.	4
——,—Scouring	"	"	"	4
Rifle Balls,—Moulds for	Lewis Evans,	Morgantown,	Va.	18
Rock-drilling Machines,	L. M. Gilmore,	Janesville,	Wis.	11
Ruffles,—Manufacture of	G. B. Arnold,	City of	N. Y.	25
Saddles,	J. H. Boyd,	Baltimore,	Md.	25
Saddle Trees,	S. E. Tompkins,	Newark,	N. J.	25
Sad Iron,	L. S. Chichester,	City of	N. Y.	4
Sails for Vessels,—Fore-and-aft	A. C. Tibbetts,	Rockland,	Me.	11
Salt,—Manufacture of Common	Thomas Spencer,	Syracuse,	N. Y.	25
Sap from Trees,—Collecting	E. W. Ormsbee,	Montpelier,	Vt.	4
Sap Conductors,	Homer Hecox,	Rutland,	N. Y.	4
Saw Clamp,	J. H. Dunbar,	Plymouth,	Conn.	11
—— Frames,—Wood	Wm. H. Livingston,	City of	N. Y.	18
———————	"	"	"	18
—— Grinding Machine,	Wm. Dougherty,	Philadelphia,	Penna.	25
—— Teeth,	Ira Mason,	Berlin,	N. H.	11
Saws,—Grinding	H. R. Burger,	Richmond,	Va.	11
——,—Handles to Cross-cut	Isaac Pelham,	Ithaca,	N. Y.	25
——,—Wood	Augustus Pruyn,	Albany,	"	11
Sawing Machine,—Hoop	Joseph Raub,	Highland,	Penna.	11

Sawing Out Shingles,	J. R. Hall,	Brunswick,	Me.	11
School Desk,	Amos Chase,	N. Weare,	N. H.	11
School Desks,—System of	S. L. Wilkinson,	Cross Plains,	Tenn.	18
Seed Planters,	W. H. Barber,	Wolcottville,	Conn.	4
———	W. W. Golsan,	Autaugaville,	Ala.	4
———	A. F. Hines,	Washington,	D. C.	4
Seeding Machines,	Ball & Nauman,	Dayton,	Ohio,	25
———	Benjamin Barnard,	Farmington,	"	25
———	David Eldred,	Monmouth,	Ill.	25
———	A. R. Park,	Columbia,	Texas,	4
Sewing ———	G. B. & A. Arnold,	City of	N. Y.	25
———	Dwight Tracy,	Worcester,	Mass.	11
———	T. S. Washburn,	Rochester,	N. Y.	11
Sheathing Ships, &c.,	John Revere,	Boston,	Mass.	4
Shingles,—Sawing	August Pernot,	Chilton,	Wis.	4
Ship-building,	S. L. Pionnier,	City of	N. Y.	4
Ships Air Ports,	Maupin & Rooke,	Portsmouth,	Va.	18
—— Windlass,—Vertical	Charles Perley,	City of	N. Y.	11
Shirt Bosoms,	Ira Perego, Jr.,	"	"	25
Shirting,—Evening the Edges of	A. T. Underhill,	"	"	11
Shoe Lasts,	Franklin Maynard,	Cambridge,	Mass.	25
Skates,	Luther Fogg,	Boston,	"	4
Smoothing Iron and Lamp,	Leonard Bricker,	Springfield,	Ill.	11
Smut Machines,	H. W. Shipley,	Mt. Vernon,	Ohio,	11
—— and Scouring Machines,	James White,	Cleveland,	"	25
Sowing Machines,	J. L. Garlington,	Snapp'g Shoals,	Ga.	25
———	W. D. Mason,	Jarratt's Depot,	Va.	4
Spoke-shave,	Samuel Leonard,	Bridgewater,	Mass.	18
Staves,—Jointing	Wm. Robinson,	Augusta,	Ga.	11
———,—Riving and Dressing	"	"	"	11
Stables for Horses, &c.,—Safety	Wm. E. McIntire,	Salem,	Mass.	18
Stave Jointer,	Edmund Greenlee,	Summerhill t'p,	Penna.	11
—— Machines,	S. F. Gelston and others,	Buffalo,	N. Y.	25
Steam Boilers,—Grates for	F. A. Hull,	Belvidere,	Ill.	11
——— Engines,	Wallace Wells,	City of	N. Y.	11
———,—Cut-off valves	George Frost,	Brooklyn,	"	25
———,—Governors for	S. H. Miller,	Hanoverton,	Ohio,	11
———,—Oscil. Valves	George Burnham,	Pittsburgh,	Penna.	25
——— Hammers,	Thomas Beach	Freeport,	"	4
——— Heating Apparatus,	C. A. Wilson,	Cincinnati,	Ohio,	4
Steel,—Converting Iron into	E. G. Pomeroy,	City of	N. Y.	4
———	Thomas Sheehan,	Dunkirk,	"	4
Stench Trap for Sinks,	Alfred Carson,	City of	"	25
Stirrups,	D. W. Clark,	Stratford,	Conn.	11
Stoves,	W. B. Treadwell,	Albany,	N. Y.	18
———,—Cooking	Zebulon Hunt,	Hudson,	"	25
———,—Fruit Dry'g	D. C. Colby,	Newport,	N. H.	18
Stove Grate,	J. W. Parnell,	Troy,	N. Y.	25
Straw Cutters,	Wm. B. Kern,	Middlebourne,	Va.	18
———,—Feeder for	Daniel Fasig,	Rowsburg,	Ohio,	4
Street Paving,—Rammer for	Wm. Beach,	Philadelphia,	Penna.	18
Sugar-cutting Machine,	Charles Kingler,	City of	N. Y.	25
Sugar,—Refining	H. G. C. Paulsen,	"	"	18
Swifts,	M. Hemingway,	Watertown,	Conn.	18
Scythes,—Hardening	Holman & Kelly,	Slaterville,	R. I.	18
Tanning,—Apparatus for	Wm. H. Heald,	Baltimore,	Md.	11
Teaching Children,	J. J. Johnston,	Alleghany,	Penna.	4
Thread-dressing Machines,	Julius Loeb,	City of	N. Y.	11
Threshing Machines,	David Barger,	Columbia,	"	11
———	A. B. Crawford,	Piqua,	Ohio,	4
Tiles,—Blocks for Forming	James Molyneux,	Bordentown,	N. J.	11
Tobacco,—Straightening, &c.,	W. W. Justis,	Genito,	Va.	11

Toilet,—Composition for	Sampson American,	Chicago,	Ill.	11
Treadle Connexion for Machin'y,	A. A. Raymond,	Salem,	Mass.	11
Trip Hammer,	Alexander Morton,	City of	N. Y.	18
Tuck and Plait Folders,	Reuben Brady,	"	"	4
Turning Ovals,—Machines for	I. S. Barber,	"	"	4
Umbrella Sticks,—Wood for	Jonathan Ball,	Elmira,	N. Y.	4
Valves,—Slide	James Millholland,	Reading,	Penna.	25
———	John Randall,	Elmira,	N. Y.	25
Veneers,—Chamfering	George Williamson,	Newark,	N. J.	4
Vulcanized Rubber,—Restoring	D. D. Parmelee,	Salem,	Mass.	25
Wash-board,	A. Hoagland,	Jersey City,	N. J.	11
Washing Machine,	S. W. Mudge,	Rome,	N. Y.	18
——— ———	Wm Shafer,	Ripon,	Wis.	11
——— ———	C. D. and S. M. Ober,	Morrisville,	Vt.	11
Watches,	E. G. Elliot,	Elk Horn,	Wis.	11
Wells, &c.,—Rais'g Water from	Joel Lee,	Galesburg,	Ill.	18
Wheels,—Car	Wade & Kaye,	Pittsburgh,	Penna.	4
———,—Tightening Tires on	Everett Bass,	Calhoun co.,	Ga.	11
Whiffle-trees for Vehicles,	M. C. Chamberlin,	Johnsonsburg,	N. Y.	11
Windmills,	J. R. Babcock,	Canandaigua,	"	18
Window Sashes,—Hanging	L. W. Thickstun,	Chatfield,	Minn.	18
——— Shutter Stands,	J. W. Knapp,	Chester,	N. Y.	4
Wine Presses,	Wm. S. Kimball,	Rochester,	"	4
Wood-screws,	George Freeman,	City of	"	11

EXTENSIONS.

Acids,—Separat. Oleic & Stearic	J. S. Gwynne,	City of	N. Y.	4
Sewing Machines,	Elias Howe, Jr.,	Brooklyn,	"	11
Stoves,	J. H. B. Latrobe,	Baltimore,	Md.	4

ADDITIONAL IMPROVEMENTS.

Corn Planters,	W. C. Banks,	Como Depot,	Miss.	4
Hay.—Loading	T. J. Jolly,	Olean,	Ind.	4
Stoves,	G. J. Kingsbury,	Rochester,	N. Y.	18

RE-ISSUES.

Bags,—Making Paper	E. W. Goodale,	Clinton,	Mass.	4
Cameras.—Plate-holder for	A. S. Southworth,	Boston,	"	25
Cloth,—Drying	B. Sexton,	E. Windsor,	Conn.	25
Cordage,—Manufacturing	Wm. Jostin,	Cleveland,	Ohio,	25
Grain Separators,	J. L. Booth,	Rochester,	N. Y.	25
Hay Making Machines,	J. C. Stoddard,	Worcester,	Mass.	11
Lamps,	M. A. Dietz,	Brooklyn,	N. Y.	4
———	Wm. Fulton,	Cranberry,	N. J.	25
———.—Vapor	A. M. Mace,	Springfield,	Mass.	4
Ovens,—Bakers	Hiram Berdan,	City of	N. Y.	11
Printing Presses,—Feeding	S. and G. H. Ferguson,	Malden Bridge,	"	25
Ploughs,—Gang	Henry Cowing,	Corpus Christi,	Texas,	11
Railroads,—Sleeping Cars for	Eli Wheeler,	Elmira,	N. Y.	18
Roofing Compositions,	Henry Lester,	Cincinnati,	Ohio,	18
Seed Planters (5 Patents),	G. W. Brown,	Galesburg,	Ill.	11
Steam Engines,—Regulat. Valve	N. C. Travis and others,	Alton,	"	25

DESIGNS.

Sad Irons,	Thomas Loring,	Blackwoodt'n,	N. J.	25
Stove,—Plates of a	Horton & Martine,	Philadelphia,	Penna.	25
——,——— Cylinder	"	"	"	25
——,—Cooks	W. W. Stanard,	Buffalo,	N. Y.	25
———	"	"	"	25
Stoves,	N. S. Vedder,	Troy,	"	4
Washington Irving,—Medallion	Marie L. Livingston,	City of	"	4

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, November 15, 1860.

John C. Cresson, President, in the chair.

John Agnew, Vice-President,
Isaac B. Garrigues, Recording Secretary, } Present.

The minutes of the last meeting were read and approved.

Letters were read from Eli W. Blake, Esq., New Haven, Conn.; and Jos. Wharton, Esq., Bethlehem, Penna.

Donations to the Library were received from the Royal Institution, the Royal Astronomical Society, and the Zoological Society, London; the Literary and Philosophical Society, Liverpool, England; the K. K. Geologischen Reichsanstalt, the K. K. Geographischen Gesellchaft, and the Oesterreichischen Ingenieurs Verienes, Vienna, Austria; Frederick Emmerick, Esq., Washington, D. C.; the Providence Athenæum, Providence, R. I.; Samuel Clark, Esq., City of New York; Henry Howson, Esq., and Prof. John F. Frazer, Philadelphia.

The Periodicals received in exchange for the Journal of the Institute, were laid on the table.

The Treasurer's statement of the receipts and payments for the month of October was read.

The Board of Managers and Standing Committees reported their minutes.

Eight resignations of membership in the Institute were read and accepted.

Candidates for membership in the Institute (14) were proposed, and the candidates proposed at the last meeting (18) duly elected.

Blake Brothers sent a cut and description of their Ore and Stone Breaker, with an invitation to the members to witness its operation at a quarry near Germantown. It consists of a heavy cast iron frame, carrying a movable hinged jaw, operated by a toggle-joint which takes its motion from a lever and a crank of short throw. Every revolution of the crank gives about one-quarter of an inch motion to the end of the jaw, which hangs nearly vertical, and so as to form, in connexion with the frame, a chamber for the reception of the stone. The size of this chamber varies with the size of the machine, being at the top from 10 ins. long by 5 ins. wide, to 20 ins. long by 7 ins. wide; whilst the bottom area, or exit for the broken stone, has the same length as the top, but of such width as may be desired to produce stone of the required size; the adjustment being made by a wedge and screw, or by substituting longer or shorter bars in the toggle-joint.

"The product of these machines per hour, in cubic yards, of fragments, will vary considerably with the character of the stone broken. Stone that is granular in its fracture, like granite and most kinds of sandstone, will pass through more rapidly than that which is more compact in its structure. The kind of stone being the same, the product per hour will be in proportion to the width of the jaws, the distance between them at the *bottom*, and the speed.

"The proper speed is about 200 revolutions per minute; and to make good road metal from hard compact stone, the jaws should be set from 1¼ to 1½ ins. apart at the bottom. For softer and for granular stones they may be set wider."

The following table will give an idea of the capacity of the breaker.

Size of chamber at top.	Product per hour.	Power required.
10″ × 5″	3 cubic yards.	6 horses.
15 × 5	4½ "	9 "
20 × 7	6 "	12 "

These machines are in use at the Central Park and new Reservoir, N. Y., Cooper & Hewitt's blast furnace, and at Graff, Bennett & Co.'s, Pittsburgh, and are said to give satisfaction in all cases.

Mr. Joseph Wharton, of the Lehigh Zinc Works, sent an ingot of pure Zinc for the inspection of the members. The ore from which it was made is obtained from the mines of the Lehigh Zinc Co., near Bethlehem, Penna., at which town the works are located. About 30 tons of metal are produced weekly, and when the furnaces are all in operation the production will be increased to two thousand tons per annum. All the articles required in the manufacture of the zinc are made upon the premises: as retorts, muffels, fire-bricks, &c., of ingredients brought from the surrounding country, no foreign material being used. This zinc is claimed to be equal to the best distilled zinc sold by manufacturing chemists. Prof. Booth, U. S. Mint, Prof. Bruel, Yale College, Mr. C. W. Eliot, and Mr. F. W. Storer, have examined and approve its quality.

A Rain Conductor, taken from the Farmers Market, was placed upon the table. Several of the conductors attached to the Market were, shortly after a heavy rain storm, found to be collapsed. This may have been owing to a sudden stoppage of the conductors near the top by shavings, and the consequent formation of a vacuum by the discharge of the water below the obstruction. Or, the water in falling through the conductor has, in obedience to the law of gravity, become attenuated more and more as it neared the ground, whilst the air has been carried along with its current, causing a partial vacuum, which the material of the conductor was not able to withstand. As a parapet wall surrounds the roof, a head of water was above the entrance to the conductors, and consequently no air could enter to supply the place of that drawn off, and a collapse resulted. The remedy would have been—perforations at intervals.

The President, at the request of the Committee on Meetings, gave an account of two remarkable instances illustrating the tendency of electrical discharges to disperse in different directions, when conducting bodies situated near its path are presented.

One of these was that of the destruction of several panels of a post and rail fence, on the farm of Israel W. Morris, situated near the western part of the city. The lightning appeared to have struck a

maple tree standing on a small knoll in the line of the fence, and descending along the bark of the tree, without apparent injury, to the level of the rails near the ground, diverged in opposite directions along the fence, splitting the rails and bursting open the posts for the distance of eight panels each side, where it seems to have been conveyed into the earth.

The other case was that of a stroke of lightning on the line of telegraph belonging to the City Gas Works. In this instance, the flash was seen to dart upon a cherry tree standing about 60 feet south of the line of wires, and then to pass along the line in opposite directions, having the appearance of balls of fire leaping from pole to pole. The portion of the charge passing eastward was traced for the distance of 1500 feet by the destruction of the poles, many of which were so shattered as to let the wires drop to the ground, and others splintered more slightly. Going west, the poles were uninjured, the charge reaching the ground in that direction through the ground wire and the lightning protectors of the instruments at the First Ward station of the Gas Works, distant about 3100 feet from the point of reception. The instruments that were connected with the line were uninjured, but others which were not connected were greatly damaged; the copper wires being fused, and the glass case covering one of them shattered as if by an explosion from within.

The instruments referred to by the President were placed on the table for inspection by the members.

METEOROLOGY.

The Meteorology of Philadelphia. By JAMES A. KIRKPATRICK, A.M.

OCTOBER.—The temperature of October was over four degrees higher than that of October, 1859, and about half a degree above the average temperature of the month for the last ten years. The warmest day of the month was the 2d, of which the mean temperature was 69°, and the thermometer reached the maximum (79°) on the same day. The 14th of the month was the coldest day, the mean temperature being 43½°. The temperature was lowest (36°) on the night of the 14th, during a storm of rain. On the same day, on the north of the city, and throughout northern Pennsylvania and southern New York, the first snow of the season fell. On the 15th, 16th, and 17th, the temperature increased gradually, and from the 18th till the end of the month, remained at about an average of 57°, with but little range, at no time being below 44°.

Both the daily oscillation and the mean daily range of temperature were less than for the same month last year, though they were slightly above the average for ten years.

The force of vapor and the relative humidity were above the average for the first time since last May; the increase in the former being more marked at 9 P. M., and in the latter at both 2 and 9 P. M.

Rain fell at Philadelphia on thirteen days of the month, to the ag-

gregate depth of 4·685 inches, which is nearly two inches above the average for the month, and an inch and a half more than fell in October, 1859. It is more than fell in any other October for the last ten years; the nearest approach to the amount was in October, 1853, when 3·47 inches fell.

The pressure of the atmosphere was two-hundredths of an inch greater than the average, and nearly one-tenth of an inch greater than in October, 1859. The barometric column stood highest on the morning of the 1st of the month, when it indicated 30·275 inches, though the average height for a day was greatest on the 28th. It was lowest (29·312 inches) on the afternoon of the 8th.

There was but one day of the month on which the sky was completely clear, or free from clouds; and there were six days on which the sky was completely covered with clouds, at the hours of observation.

The winds during the month were but one degree nearer the west than in September, and still very nearly as far south of west as the resultant for the month for the last ten years is north of west.

The earthquake which extended throughout Canada and over all of the Eastern States, on the morning of Wednesday, the 17th of October, was not felt, or, at any rate, not noticed, at Philadelphia.

A Comparison of some of the Meteorological Phenomena of October, 1860, with those of October, 1859, and of the same month for ten years, at Philadelphia.

	Oct., 1860.	Oct., 1859.	Oct., 10 years.
Thermometer.—Highest,	79°	81·5°	9 °
" Lowest,	36	30·0	28
" Daily oscillation,	16·10	18·10	15·60
" Mean daily range,	5 80	5 90	5·60
" Means at 7 A. M.,	51·58	46·98	50·97
" " 2 P. M.,	63·29	59 11	63·03
" " 9 P. M.,	55·61	50·87	55·17
" " for the month,	56·83	52·32	56·39
Barometer.—Highest,	30·275 in.	30·193 in	30·410 in.
" Lowest,	29·312	29·470	29·012
" Mean daily range,	·119	·140	·143
" Means at 7 A. M.,	29 963	29·864	29 937
" " 2 P. M.,	29 906	29 823	29 895
" " 9 P. M.,	29 938	29 850	29 915
" " for the month,	29·936	29·845	29 916
Force of Vapor.—Means at 7 A. M.,	·321 in.	·259 in.	·312 in.
" " " 2 P. M.,	·363	·274	·344
" " " 9 P. M.,	·354	·280	·316
Relative Humidity.—Means at 7 A. M.,	80 per ct	75 per ct.	78 per ct.
" " " 2 P. M.,	61	50	56
" " " 9 P. M.,	77	69	73
Rain, amount in inches,	4·685	3·210	2 781
Number of days on which rain fell,	13	7	9
Prevailing winds,	s. 75°58′ w·069	s. 75°21′ w 405	s. 73°32′ w·255

Abstract of Meteorological Observations for September, 1860; made in Philadelphia, Franklin, and Somerset Counties, Pennsylvania, for the Committee on Meteorology of the Franklin Institute.

PHILADELPHIA.—Lat. 39° 57′ 28″ N. Long. 75° 10′ 28″ W. Height above the sea 50 feet. Prof. J. A. KIRKPATRICK, Observer.

CHAMBERSBURG, Franklin Co. Lat. 39° 58′ N. Long. 77° 45′ W. Height 618 ft. WM. HEYSER, Jr., Obs.

SOMERSET, Somerset Co. Lat. 40° N. Long. 79° 3′ W. Height 2195 feet. GEO. MOWRY, Observer.

1860. Sept.	Philadelphia. Barometer. Mean.	Barometer. Mean daily range.	Thermometer. Mean.	Thermometer. Daily oscillation.	Thermometer. Mean daily range.	Force of vapor. 2 P.M.	Relative humidity. 2 P.M.	Rain.	Prevail'g winds.	Chambersburg. Barom. Mean.	Thermom. Mean.	Thermom. Mean daily range.	Force of vapor. 2 P.M.	Relative humidity. 2 P.M.	Rain.	Prevail'g winds.	Somerset. Barom. Mean.	Thermom. Mean.	Thermom. Mean daily range.	Force of vapor. 2 P.M.	Relative humidity. 2 P.M.	Rain.	Prevail'g winds.
	Inch.	Inch.	°	°	°	Inch.	Per ct.	Inches.	Direc.	Inch.	°	°	Inch.	Per ct.	Inch.	Direc.	Inch.	°	°	Inch.	Per ct.	Inch.	Direc.
1	29·817	·125	71·0	22	4·2	·459	46		N W.	29·216	66·7	4·0	·385	52		W.	27·678	60·3	5·7	·408	50		W.
2	30·087	·270	66·8	20	5·2	·307	38		N W.	29·447	63·0	3·0	·398	56		(var.)	27·831	59·3	4·3	·442	54		W N W
3	30·152	·065	68·2	18	2·3	·396	44		(var.)	29·541	68·3	5·3	·449	61		E.	27·895	63·7	6·3	·448	61		S E.
4	30·160	·071	70·0	25	2·8	·445	43		(var.)	29·507	70·3	2·0	·581	72		E.	27·870	66·0	1·7	·567	67		S E.
5	30·017	·143	75·3	20½	5·3	·617	53		S S W.	29·368	73·0	3·3	·677	66		E.	27·791	68·7	4·0	771	78		S W.
6	29·974	·043	75·3	14	2·0	·700	66	0·072	S S W.	29·331	73·0	3·3	·744	86	0·575	E.	27·770	73·3	4·7	·772	71		E S E.
7	29·953	·025	78·5	20	3·2	·743	58		S W.	29·300	74·3	2·7	·772	80		E.	27·756	74·7	1·3	·826	70	0·027	S W.
☾ 8	29·755	·198	80·3	21	2·2	·822	56	0·032	S W.	29·138	77·0	2·7	·816	75	1·180	(var.)	27·629	73·0	2·3	·859	79	1·372	W.
9	29·910	·173	62·8	18	17·5	·313	47		N.	29·379	63·3	13·7	·330	53		(var.)	27·741	52·3	20·7	·281	58		N.
10	29·934	·079	62·7	24	5·5	·348	47		S W.	29·287	60·7	6·7	·389	63		W.	27·691	56·0	9·7	·455	63		W.
11	29·812	·122	63·7	10	4·3	·435	68	0·165	N E.	29·175	63·3	3·0	·398	56		(var.)	27·627	55·7	2·3	·366	52	0·375	W.
12	29·783	·115	55·7	12	8·0	·224	43	0·127	N W.	29·274	53·0	10·7	·225	57		(var.)	27·718	48·7	9·0	·270	72		N W.
13	30·051	·268	57·8	22	5·8	·219	36		N W.	29·500	56·0	3·7	·314	53		W.	27·896	47·7	4·3	·295	59		N W.
14	30·252	·201	63·5	25	5·7	·325	39		S W.	29·6·4	58·3	3·0	·425	64		S E.	27·975	55·0	10·0	·408	50		S E.
● 15	30·228	·029	66·0	24	2·5	·455	47		S W.	29·554	62·7	3·7	·459	58		S E.	27·948	60·3	5·0	·491	53		?
16	30·017	·211	68·8	24	2·8	·504	48		S W.	29·472	66·7	4·0	·601	65		E.	27·761	66·0	5·7	·526	57	0·221	S W.
17	29·894	·123	70·5	16	5·7	·587	68		S S W.	29·246	65·7	6·3	·577	84	0·085	(var.)	27·679	60·0	6·0	·462	65		S E.
18	29·972	·078	72·7	20½	2·5	·556	54		S W.	29·335	67·0	2·7	·608	80	0·210	E.	27·723	63·7	4·3	·581	71		S S E.
19	29·955	·025	74·7	18	2·0	·619	59		S E.	29·265	71·0	4·0	·704	81		S E.	27·697	67·0	3·3	·594	63		S S E.
20	29·682	·273	74·3	14	1·7	·769	78	2·056	S W.	29·064	71·3	1·7	·704	81	2·477	W.	27·535	62·3	6·7	·534	59	0·108	(var.)
☽ 21	29·871	·188	60·7	17	13·7	.260	41		W N W	29·273	58·7	12·7	·427	77		(var.)	27·681	49·3	13·0	·282	54		W.
22	30·073	·202	60·8	22	4·8	·280	38		S W.	29·380	57·0	7·7	·303	46		(var.)	27·767	55·0	9·7	·370	49		S W.
23	30·004	·069	68·7	23	7·8	·502	51		S W.	29·345	65·0	8·0	·505	56		W.	27·776	62·7	7·7	·518	60		W.
24	29·936	·068	69·7	22	1·3	·445	43		(var.)	29·222	66·0	2·3	·532	63	0·374	W.	27·650	64·3	2·3	·520	55		W S W
25	29·676	·260	70·8	15	2·8	·556	54	0·055	S W.	29·051	67·7	1·7	·462	55		W.	27·536	64·7	3·7	·614	68	0·058	W.
26	29·992	·316	60·3	14	10·5	·282	44		W.	29·416	60·7	7·0	·314	53		E.	27·831	49·0	15·7	·309	60		W.
27	30·135	·143	51·5	10	8·8	·203	73	0·370	W.	29·464	52·7	8·3	·375	93	0·234	(var.)	27·821	45·0	6·0	·273	84	0·409	S E.
28	30·034	·123	55·8	18	5·3	·281	47		N W.	29·436	54·7	3·7	·297	55		E.	27·812	48·3	6·0	·242	52		N W.
○ 29	30·232	·198	50·3	17	5·5	·161	35		N W.	29·591	48·7	5·3	·295	68		E.	27·921	44·0	7·0	·254	53		S W.
30	30·304	·072	48·3	10	3·3	·187	49		N W.	29·637	48·0	2·7	·308	79		E.	27·920	41·7	11·7	·221	83		E.
Means	29·989	·143	65·8	18	5·2	·437	50	2·907	S 74° W	29·357	63·5	5·0	·480	66	5·135	S 45° E	27·764	58·5	6·7	·465	62	2·570	S 63° W

Abstract of Meteorological Observations for September, 1860; made in Adams, Dauphin, Northumberland, Centre, and Erie Counties, Pennsylvania, for the Committee on Meteorology of the Franklin Institute.

	Gettysburg, Adams Co. Lat. 39° 49′ N. Long. 77° 18′ W. Ht. 624 ft. Prof. M. Jacobs, Obs.					Harrisburg, Dauphin Co. 40°16′, N. 76°50′, W. Ht., 300 ft. John Heisely, M.D., Obs.					Shamokin, Northumberland Co. 40° 45′ N. 76° 30′ W. Height, 700 ft. P. Friel, Obs					Fleming, Centre Co. 40° 55′ N. 77° 53′ W. Ht., 780 feet. S. Brugger, Obs.					Erie, Erie Co.—Lat. 42° 8′ N. Long. 80° 12′ W. Height about 640 feet. Benjamin Grant, Obs.							
1860.	Barom	Thermom.				Barom	Thermom.				Thermom.					Thermom.					Barom	Thermom.		Force of Vapor.	Relative humidity.			
Sept.	Mean.	Mean.	Mean daily range.	Rain.	Prevail'g winds.	Mean.	Mean.	Mean daily range.	Rain.	Prevail'g winds.	Mean.	Mean daily range.	Rain.	Prevail'g winds.		Mean.	Mean daily range.	Rain.	Prevail'g winds.		Mean.	Mean.	Mean daily range.	2 P. M.	2 P. M.	Rain.	Prevail'g winds.	
	Inch.	°	°	Inch.	Direc.	Inch.	°	°	Inch.	Direc.	°	°	Inch.	Direc.		°	°	Inch.	Direc.		Inch.	°	°	Inch.	Per ct.	Inch.	Direc.	
1	29·405	65·3	4·7		N W.	29·662	70·7	3·0		N W.	59·0	11·0		(var.)		62·0	4·3		(var.)		29·433	63·3		·440	64		N W.	
2	29·645	63·7	3·0		N E.	29·945	66·7	4·0		N.	57·3	1·7		E.		58·7	5·3		W.		29·518	61·7	1·7	·408	60		E.	
3	29·754	66·3	2·7		(var.)	30·046	69·7	3·7		E.	63·3	6·0		S E.		63·0	6·3		S W.		29·508	65·7	4·0	·537	61		S.	
4	29·698	66·3	0·7		S S W.	30·008	72·3	3·7		(var.)	66·0	5·3		(var.)		68·0	8·3	0·050	S W.							0·110	S.	
5	29·544	75·0	9·0		S S W.	29·857	78·0	5·7		(var.)	73·7	7·7	0·121	(var.)		74·0	6·0		W.								S.	
6	29·533	73·0	4·0	0·095	S.				0·497	(var.)	74·0	2·3		E.		73·0	3·7	0·575	W.		29·349	75·7		·741	70		W.	
7	29·499	76·3	3·3		(var.)	29·772	78·7			S W.	73·3	5·3		S E.		73·3	3·0		(var.)							0·70	N.	
8	29·358	77·7	2·0	1·060	(var.)	29·614	80·3	3·7		S W.	76·0	3·3	0·304	W.		71·3	5·3	0·410	W.									
9	29·519	57·7	20·0		N.	29·803	63·7	16·7		N.	57·3	18·7		W.		54·3	17·0		N W.									
10	29·488	57·7	7·3		S W.	29·779	62·3	4·0		S W.	55·0	7·7		(var.)		56·3	9·3		S E.									
11	29·383	61·3	3·7	0·025	S W.	29·670	66·0	3·7		S W.	60·0	6·3		W.		57·7	7·3	0·220	N W.					·445	56		N.	
12	29·466	52·3	9·0		N W.					N W.	49·3	10·7	0·400	W.		52·7	6·3		N W.		29·458	52·7		·214	36		N.	
13	29·700	54·3	4·7		N W.	29·942	60·7			N W.	51·7	8·3		W.		52·0	1·3		N W.		29·579	55·7	3·0	·323	47		W.	
14	29·841	57·3	5·7		S W.	30·107	62·7	2·7		S W.	54·0	9·0		W.		55·7	7·7		W.		29·562	66·0	10·3	·298	45		W.	
15	29·777	61·3	4·0		S.	30·054	66·7	4·0		S W.	59·3	5·3		(var.)		58·0	2·3		(var.)		29·460	73·3	7·3	·431	55		S W.	
16	29·548	66·7	4·7		(var.)	29·832	70·7	4·0		S W.	67·7	8·3		S E.		63·0	9·0		W.		29·256	68·7	6·0	·534	61		S W.	
17	29·482	65·3	7·3		S S W.	29·727	69·7	6·3		(var.)	62·7	10·7		E.		64·0	5·7	0·185	S W.		29·313	61·7	7·0	·426	55		N.	
18	29·536	69·3	4·0	0·165	(var.)	29·810	70·0	5·0		N E.	69·3	12·3	0·183	E.		65·3	5·3		(var.)		29·321	61·7	3·3	·479	58		(var.)	
19	29·492	70·7	1·7	0·940	S S W.	29·780	74·3	4·3	0·560	S W.	70·7	6·0	0·052	E.		71·0	5·7		W.		29·316	68·0	6·3	·472	57		W.	
20	29·277	70·3	2·0	0·240	S.	29·556	73·7	2·0	0·075	(var.)	69·3	1·3	0·250	(var.)		66·3	5·3	0·210	S W.		29·124	69·3	7·7	·424	54	0·140	(var.)	
21	29·434	57·3	16·3		W.	29·729	61·3	12·3		N W.	54·0	13·3		(var.)		51·7	14·7		N W.		29·260	51·3	9·0	·333	48	1·185	S W.	
22	29·612	56·0	8·0		S S W.	29·862	61·7	5·7		W.	54·3	12·3		(var.)		55·3	9·7		N W.		29·265	62·7	11·3	·359	50	0·030	S W.	
23	29·561	65·7	9·7		S.					S W.	66·7	12·3		W.		63·3	8·0		(var.)		29·322	64·0	1·3	·487	58	0·150	N E.	
24	29·442	66·3	1·3		S W.	29·702	71·7			S W.	67·0	1·0		E.		65·0	3·0		(var.)		29·139	70·7	6·7	·424	54		S W.	
25	29·242	69·7	3·3	0·020	N W.	29·503	71·7	5·3		N W.	62·0	13·0	0·600	W.		65·7	8·0	0·300	W.		29·089	62·3	8·3	·328	47	0·770	(var.)	
26	29·608	57·7	12·0		(var.)	29·868	62·3	9·3		W.	58·7	5·3		W.		58·0	7.7		N W.		29·483	56·3	6·0	·251	40		N W.	
27	29·717	49·0	8·7	0·188	(var.)	29·960	54·0	8·3	0·244	(var.)	49·3	9·3		S E.		54·0	2·7		S E.		29·483	58·5	3·3	·314	46		S E.	
28	29·662	53·7	4·7		W.	29·882	57·7	5·7		N W.	53·7	4·3		(var.)		50·0	6·7		W.		29·545	52·3	6·0	·187	33	0·070	N E.	
29	29·833	49·0	4·7		N W.	30·090	51·0	6·7		N.	42·7	11·0		(var.)		49·0	4·3		N W.		29·686	46·0	6·3	·196	34		E.	
30	29·869	46·3	5·3		N W.	30·162	48·7	3·7		N E.	49·0	3·3		(var.)		45·0	4·0		S E.		29·627	48·7	3·3	·216	36		E.	
Means	29·563	62·9	5·9	2·733	s 72° w	29·842	66·6	5·5	1·376	s 88° w	60·7	7·7	1·910	s 4° e		60·5	6·4	1·950	n 86° w							3·155	s 74° w	

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